# ALTERNATIVE FUELS AND COMPATIBLE ENGINE DESIGNS



## HEARING

BEFORE THE

## SUBCOMMITTEE ON ENERGY AND POWER

OF THE

## COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE HOUSE OF REPRESENTATIVES

NINETY-SIXTH CONGRESS

SECOND SESSION

ON

COST AND FLEXIBILITY OF METHANOL AS A FUEL, GOVERNMENT INITIATIVES TO ACCELERATE ITS USE, AND THE POTENTIAL IMPACT IT MAY HAVE ON DOMESTIC ENTERPRISES

DECEMBER 18, 1980

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# ALTERNATIVE FUELS AND COMPATIBLE ENGINE DESIGNS

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THURSDAY, DECEMBER 18, 1980

House of Representatives,
Subcommittee on Energy and Power,
Committee on Interstate and Foreign Commerce,
*Washington, D.C.*

The subcommittee met, pursuant to notice, at 10 a.m. in room 2123, Rayburn House Office Building, Hon. Richard L. Ottinger presiding (Hon. John D. Dingell, chairman).

Mr. Ottinger. The subcommittee will come to order.

On June 25 of last year, this subcommittee initiated hearings on the commercialization of nontraditional liquid and gaseous fuels; that is, fuels that could be economically produced from abundant domestic resources that could displace our traditional reliance on imported oil and natural gas.

Our witnesses included engine manufacturers, engineering firms, regulatory organizations and the financial community. One answer came through loud and clear:

> Use coal as a feedstock; use known technology to get started; don't wait for the evolving technologies; and give methanol and its precurser—medium Btu gas—the most serious consideration.

Methanol seems to meet many liquid fuel requirements. Medium Btu gas, in a like fashion, can serve as a substitute for natural gas for industrial applications, which account for about 40 percent of our natural gas used.

Both methanol and medium Btu gas can be produced from coal, our most abundant national fossil fuel, and this can be done in an environmentally sound fashion. Furthermore, methanol can be made from almost any hydrocarbon available locally in different regions of the country and around the world. Thus, where available, you can use peat, garbage, biomass, or virtually any carbonous material.

Current evidence suggests that methanol as a fuel holds not only the promise of significant efficiency improvements over gasoline due to its higher natural octane, but also is less problematic in its emissions.

Medium Btu gas has similar advantages in that it burns more efficiently than natural gas and also makes a more flexible chemical feedstock than pure methane.

The hearing today is focused on three basic areas:

The cost and flexibility of methanol as a fuel in terms of raw material feedstock, engine compatibility, and plant size and technological readiness. That is the first issue.

The second relates to activities that could or should be undertaken by the Federal Government to initiate and accelerate its broad-scale use as a displacer of high-cost imported petroleum. One of the many outstanding failures of the Federal energy program is a lack of priority on alcohol fuels.

As a final and related point, we would like to examine the potential impact that the development of markets for this fuel could have on the competitiveness of the liquid fuel industry as well as the potential impact it could have on the transportation segment of our economy, which uses 54 percent of our oil.

It is clear that if we are to reduce the $75 billion per year we are currently spending on oil imports, the national security and economic peril of that dependence, we must impact the transportation sector, and methanol is one of the most promising yet most ignored solutions.

I would like to point out that even the Exxon Corp.'s president, Randall Meyer, in an address on May 5, 1980 said, "The most economic method of obtaining liquid fuels from coal with today's technology appears to be an indirect process for producing methanol."

Well, although they have not followed their words with actions, that is a strong endorsement.

We are pleased today to have very distinguished panels. The first panel consists of Mr. John Tessieri, the vice president of research and environment and safety, Texaco; Mr. Merle Fisher, vice president for administration, Bank of America; Mr. Robert J. Holtgreive, executive vice president, White Engines, Inc.; and Mr. Thomas W. Browne, vice president of United Parcel Service.

We will start with Mr. Tessieri.

Gentlemen, we would appreciate it if you would summarize your statements.

**STATEMENTS OF JOHN E. TESSIERI, VICE PRESIDENT, RESEARCH, ENVIRONMENT AND SAFETY, TEXACO, INC., ACCOMPANIED BY WILLIAM T. TIERNEY, PROJECT MANAGER, AUTOMOTIVE ENGINE DEVELOPMENT, AND R. F. WILSON, COORDINATOR, ALTERNATE ENERGY DEPARTMENT; ROBERT J. HOLTGREIVE, EXECUTIVE VICE PRESIDENT, WHITE ENGINES, INC., ACCOMPANIED BY GARY KANDEL, PROJECT ENGINEER, STRATIFIED CHARGE ENGINES; MERLE FISHER, VICE PRESIDENT FOR ADMINISTRATION, BANK OF AMERICA, ACCOMPANIED BY GARVIN McCURDY, CARSON ASSOCIATES; AND THOMAS W. BROWNE, VICE PRESIDENT, UNITED PARCEL SERVICE, ACCOMPANIED BY JIM LEWIS, AUTOMOTIVE ENGINEER**

Mr. TESSIERI. Thank you, Mr. Chairman.

I have with me today two colleagues, Mr. Bill Tierney, the project manager for automotive development on my staff, and Mr. Fred Wilson, who spent most of his career on the research side of the business but comes to us from the alternate energy department of Texaco today.

Texaco is most pleased to have the opportunity to appear before you and talk about our stratified engine development, which we call the Texaco controlled combustion system, or TCCS.

I will summarize. I would make two main points.

No. 1, to explain and show the unique technology that we are talking about in this controlled system, and also the potential for conservation that this engine brings if this technology is applied across the board to fuel, vehicle, and refinery operations.

The TCCS grew out of a research project at the Texaco Beacon Research Laboratory starting in the 1940's, when we studied the fundamentals of fuel combustion in piston engines. This led to the invention which I will describe, and it is a unique system that permits an engine to operate on a wide range of fuels with improved fuel economy.

It can use either gasoline or diesel fuel, and in either case it does not need the octane quality or the cetane quality levels that the normal engines using these fuels do require.

Mr. Chairman, I will use the chart. I think it will help to explain the process.

If there is any question with sound, just let me know, and I will give you more volume. The room sounds pretty good.

First, I would like to talk about a conventional combustion engine. This is a gasoline engine. We could have used a diesel.

You mix the fuel and the air in the carburetor and suck it into the cylinder. As the piston comes up, the spark plug fires. It starts the flame front. If the octane isn't quite right, or if there is a hot spot on the other part of the cylinder because of a deposit, a second ignition takes place. You have poor operability. You lose efficiency in the process. So that is the way the normal gasoline engines work.

Let's take a look at what we call the Texaco controlled combustion system.

Visualize first an air inlet into the cylinder which is directed in such a way that the air swirls around the cylinder, much as water would if you were to direct a hose to the side of a pail. Then as the piston comes up on the compression stroke, this gas is forced into a small combustion chamber.

That is what we are looking at here, that combustion chamber. As it is forced into the smaller combustion chamber, it actually swirls faster, much as a skater when he wants to go fast in a swirl brings his arms in.

So, with very rapid air movement, at the proper time, fuel is injected and the plug is turned on. The mixture is immediately ignited, and the flame stays there. Relatively stable, a stationary flame front.

As the swirling continues, the fuel then is fed into the flame, the combustion products are removed from it, and when the spark finally shuts off, then the last of the fuel which feeds into it circles around and is consumed.

It is the unique capability of controlling fuel air mixing and ignition that allows us to use a wide variety of fuels in this process. The excess air allows you to burn in an efficient manner, which is part of the economy.

The opportunity to use fuels is best exemplified by the fact that we have run this engine on liquified petroleum gas, the type supplied to suburban areas for cooking, jet fuel, JP–4, furnace oil, and in fact one time inadvertently someone put motor oil into the engine and it started and it operated in a satisfactory manner, even with that very heavy material. So, the wide base of capability of digesting fuel is a very important item and has been well demonstrated.

We have run it on alcohols. We have run it both on methanol and ethanol. We have found no difficulty with it, although the performance for an extended period of time would still have to be carried out.

The combustion system will take it. We believe that even more important, as these new fuels come from coal and shale in the future, which may have different characteristics than what we are looking at today, this engine will have the appetite to handle them.

Interest in this engine concept in the early days, because of the low price of fuels, was not very great. It wasn't worth investing the extra money to get an engine of this type for the economy you were faced with.

But the Army was interested in it. They were interested in the logistics of fuel supply in operation areas. So under Army contract, we successfully converted a Jeep engine to the TCCS concept. That led on to a second contract with White Engines, which developed an entirely new four-cylinder jeep engine. In both cases the engine met the performance requirement at a substantial fuel economy.

Texaco's interest in this also reaches to the other avenue; that is, the best utilization of crude that we can make to supply transportation fuel. I have a series of four cases that we looked at in which we took computer models and ran refineries in different ways to supply fuels for different types of engines.

In each case the blue represents a fixed amount of furnace oil to heat the homes, jet fuel to fly the airplanes, and diesel fuel to run the trucks. So, in each case we have the same amount of those products produced.

The size of the barrels indicates how much crude we had to use to do the job. The spotted area is how much energy we had to use in the refinery. Then finally, depending upon the sophistication of the fuel you had to make and the type of engine you were going to serve, the big yellow part, in each case had to provide the same number of transportation miles. That is important—each one supplied the same transportation.

The first case we have is the one with leaded gasoline and the gasoline engine. We are talking now about a 100,000-barrel-per-day refinery. We used that as the basis for the comparison.

The next one is the unleaded case. When unleaded gasoline was required, we had to produce octanes in the processing in the refinery. The engine had to be downrated to utilize lower octane fuel.

So you can see it cost us more energy to make the fuel. We had to use more barrels of crude in the refinery to get that fixed number of transportation miles that I talked about.

As you introduce diesel into the fleet, to the maximum that the refinery will allow, you start to see the economy of that diesel. We have a slight decrease in the cost of manufacturing, but not much.

The last one, the TCCS process, where we have looked at the fuel, the vehicle and the refinery as one, optimized the system, you see a considerable drop in the barrels of crude required to run the refinery now to satisfy that fixed amount of transportation miles.

The other important thing is we have used less energy to do that. Look at the refinery energy required—the spotted band. It is about half the base case.

I would say to you, if we have to use these refineries and take the stocks that may come from liquified coal or from shale and make today's fuels, we are going to have bigger energy consumption than we see here, even with the unleaded case.

So, the important thing is each case satisfies the same transportation miles. If we use less barrels, we are getting more miles per barrel of crude. That converts directly into conservation and it converts directly into less imported oil.

So, we think the process is very important from that overall standpoint.

In summary, then, we think the Texaco controlled combustion process is a unique process. We think it has led to an innovative engine. You will hear more of the application of this technology from the other people on the panel.

As just pointed out, we think it gives you a conservation of energy, it gives you more miles per barrel of crude. When you optimize the vehicle, the fuel, and the refinery, you have savings all the way through. It will utilize the fuels from coal and shale. It will burn alcohols, either methanol or ethanol and, as you will see from the other members of the panel, it has been demonstrated in a practical mode.

Thank you very much, sir.

[Testimony resumes on p. 25.]

[Mr. Tessieri's prepared statement and attachment follow:]

PREPARED STATEMENT OF JOHN E. TESSIERI

Mr. Chairman and Members of the Energy and Power Subcomittee of the Interstate Foreign Commerce Committee: I am John E. Tessieri, Vice President of the Research, Environment, and Safety Department of Texaco Inc. and with me today is William T. Tierney, Project Manager of Automotive Engine Development on my staff and R. F. Wilson, Coordinator from Texaco's Alternate Energy Department. I am located at the Texaco Research Center in Beacon, New York.

Texaco appreciates this opportunity to appear before you to discuss the development of our stratified charge engine concept, the Texaco Controlled-Combustion System or TCCS. The subject will be addressed in three parts. I will briefly review the development of the TCCS and show the potential impact this technology could have in improving the utilization of crude oil. Two of the major TCCS projects will be discussed by representatives of the United Parcel Service and White Engines Incorporated.

The TCCS is an outgrowth of a research project at Texaco's Beacon Laboratories that was started in the early 1940's dealing with fundamentals of fuel combustion in piston engines. This led to the invention of a unique system that would permit engine operation on a wide range of fuels with improved fuel economy. For example, it can use either gasoline or diesel fuel without regard to their octane or cetane levels. The TCCS is not sensitive to these fuel quality characteristics, although these ratings are essential for the proper operation of gasoline and diesel engines respectively.

The operation of the TCCS concept is illustrated on this chart (A). The information on all charts are included with the distributed text of my remarks. This shows the top view of a combustion chamber of a TCCS engine. The air swirl, represented by the arrow, is created during the engine's intake stroke by a specially designed intake port and valve. The air leaving the port strikes the cylinder wall and is caused to rotate much in the manner of a water jet from a hose directed tangentially into a pail. The swirl persists during the upward or compression stoke of the piston and, near the top of the stroke, when combustion is to commence, fuel is injected through the nozzle. Air mixes with the fuel and a combustible mixture is carried downstream to the vicinity of the spark plug and the mixture is then ignited. This establishes a stationary flame into which fuel and air are fed. Combustion products are continuously carried away from the flame. The power delivered by the engine is controlled only by the amount of fuel injected into the combustion chamber since there is no air throttle. It is this unique control of the sequence of fuel-air mixing and ignition that eliminates the need for an octane or cetane requirement.

The TCCS has been operated successfully on a wide range of fuels, such as gasoline, kerosine, and diesel fuel. The feasibility of operation on pure alcohols, such as ethanol or methanol, has been demonstrated but further evaluation of their effect on engine components is required.

To meet the ignition requirements of the TCCS engine, Texaco developed a unique, patented ignition system which is currently in use on the engines that will be described in presentations by UPS and White Engines.

Over the years, many technical papers were presented reporting the status of the various stages of the development of TCCS. In addition, in the early 1970's, Texaco supplied demonstration engines to manufacturers for study. During this period the interest in the TCCS was limited because of the availability of low cost fuels and the additional costs associated with the TCCS engine. However, today's fuel cost have made the TCCS engine with its improved fuel economy very attractive.

One major development program pursued under contract with the U.S. Army was a conversion of the Army "jeep" engine to the TCCS to permit operation on a wide range of fuels to simplify fuel supply logistics. Target performance requirements were satisfied with a substantial improvement in fuel economy over the standard gasoline engine.

The success of this project led to an extension of the Army contract for the development of a new, four cylinder "jeep" engine by White Engines Inc. This engine also met the performance requirements with a substantial fuel economy improvement while meeting the 1979 emissions standards for light duty trucks. At the present level of development, meeting the stringent levels of emission control required for passenger cars would impose a fuel economy penalty and constitute a potential development constraint for the TCCS. In this regard the TCCS engine is an "innovative" engine and emission standards for it should be reviewed accordingly.

There appear to be no manufacturing or material constraints in producing TCCS engines.

Texaco's interest in crude oil conservation has been the prime motivation in support of the TCCS development programs over the years. This potential of the TCCS for energy conservation was first mentioned in the United States in a paper presented before the Society of Automotive Engineers in June of 1950.

Comparison of the crude requirements for a refinery optimized to manufacture a wide boiling range fuel for TCCS powered vehicles versus refinery operations optimized to satisfy gasoline/diesel fuel markets demonstrates that significant energy conservation can result from consideration of the vehicle/ fuel/refinery (VFR) as a total system.

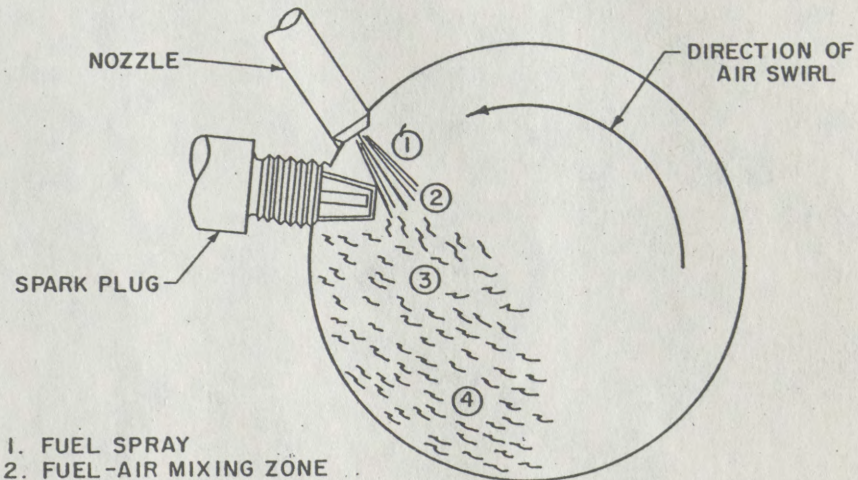
The results of a VFR study are shown in this chart (B) which is a representation of four cases dealing with different engine strategies. Each case required the supply of fuel for a fixed number of miles of transportation and fixed volumes of "protected products" (i.e.: jet fuel, home heating oil, lube oil, petrochemical feed stocks, etc.). The amount of transportation fuel produced in each case reflects the efficiency of the engines in which the fuel is used. The amount of crude oil energy used in the refinery to manufacture the product slate is also shown. Both of these influences are reflected in the amount of crude oil that must be charged to the refinery in each case. For example, a smaller refinery crude charge is a reflection of a more efficient engine and its fuel manufacturing requirements. The least amount of crude oil required to supply the fixed amount of miles of transportation means more "miles per barrel of crude" and that translates into energy conservation and less imported crude oil. This parameter for each case is compared in bar graph form in this chart (C) where it can be seen that the broad scale use of an engine such as the TCCS makes possible a substantial improvement (23% is shown) in transportation fuel utilization relative to the current trend for unleaded gasoline.

It can be seen, therefore, that simply establishing a "miles per gallon" fuel economy standard does not take into account the refinery energy required to transform the crude oil into the desired fuel type. The target should be "miles per barrel of crude oil."

This concludes my statement. Supporting information has also been submitted for the record. Thank you for your interest in our engine development project.

CHART A

TEXACO CONTROLLED - COMBUSTION SYSTEM




1. FUEL SPRAY
2. FUEL-AIR MIXING ZONE
3. FLAME FRONT AREA
4. COMBUSTION PRODUCTS

CHART B

REFINERY TRANSPORTATION FUEL PRODUCTION
VEHICLE-FUEL-REFINERY (VFR) SYSTEM

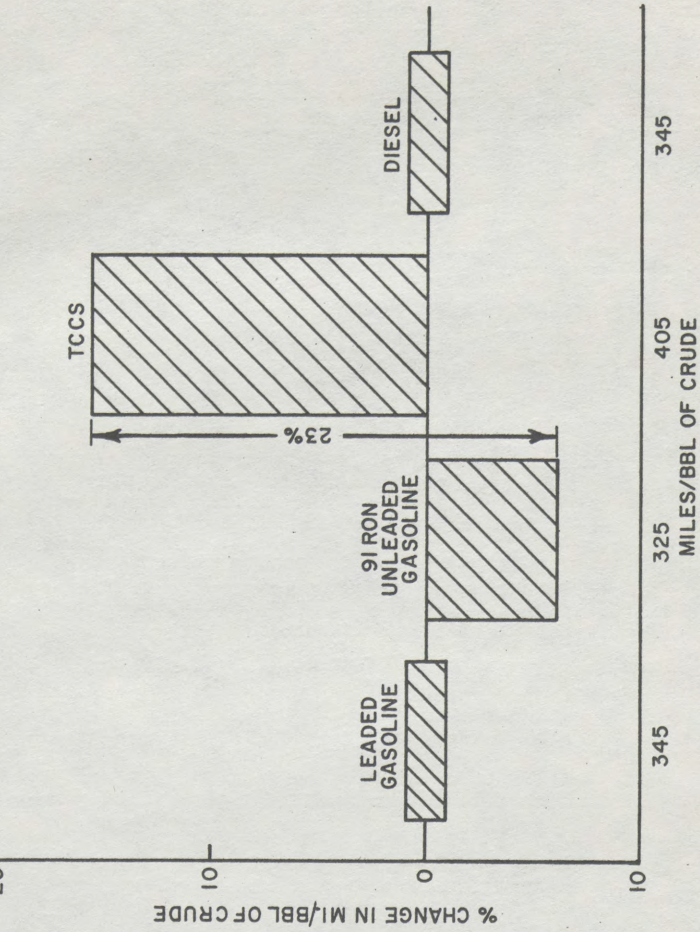
| CASE | LEADED GASOLINE | UNLEADED 91 RON | MAX DIESEL UNLEADED GASOLINE | TCCS AND BROAD RANGE FUEL (100-650°F) |
|---|---|---|---|---|
| CHARGE STOCKS BPCD* | | | | |
| CRUDE | 100,000 | 107,518 | 98,898 | 85,095 |
| OTHER STOCKS | 7,900 | 7,900 | 7,900 | 7,900 |
| | -- | -- | -- | -- |
| TRANSPORTATION FUEL BPCD* | | | | |
| GASOLINE | 54,854 | 59,893 | 33,750 | |
| DIESEL | 10,131 | 10,131 | 27,668 | 10,131 |
| 100-650° FUEL | | | | 42,195 |
| TOTAL | 64,984 | 70,024 | 61,418 | 52,326 |
| | -- | -- | -- | -- |
| REFINERY ENERGY REQUIREMENT | 8,000 | 11,504 | 7,021 | 4,425 |
| | -- | -- | -- | -- |
| PROTECTED PRODUCTS BPCD* | 34,851 | 34,851 | 34,851 | 34,851 |
| VOLUME CHANGE DUE TO PROCESSING BPCD* | -64 | +961 | -3,508 | -1,393 |

*BARRELS PER CALENDAR DAY

BASIS: 12.07 MPG (U.S. NATIONWIDE FUEL ECONOMY AVERAGE BASIS LEADED GASOLINE )
1.00 RELATIVE FUEL ECONOMY LEADED GASOLINE AVG RON-96
0.93 RELATIVE FUEL ECONOMY UNLEADED GASOLINE RON-91
1.30 RELATIVE FUEL ECONOMY DIESEL AND DIRECT INJECTION STRATIFIED CHARGE ENGINES

CHART C

## VFR EFFECTS



SUPPORTING INFORMATION

TO

STATEMENT BY

JOHN E. TESSIERI

VICE PRESIDENT

RESEARCH, ENVIRONMENT, AND SAFETY DEPARTMENT
TEXACO INC.

The information contained in this discussion is in support of the oral statement presented before the meeting of the House of Representatives Energy and Power Subcommittee of the Interstate and Foreign Commerce Committee. The text of the oral statement is included in Appendix A. The material was prepared in response to the request of December 5 from the Honorable John D. Dingell addressed to W. T. Tierney in which the details of the hearing on December 18, 1980 were outlined. A copy of this letter is in Appendix B.

The information presented herein is covered under the following subject headings:

I. Bibliography of attached Technical Papers

II. History of the Development of the Texaco Controlled-Combustion System (TCCS) Stratified Charge Engine Concept.

III. Summary of Major Study Areas in the Development of the TCCS Engine

IV. Summary of the Studies relating to the Conservation of Transportation Fuel Resources Through the Application of Fuel Efficient-Engines in the Nation's Motor Vehicle Fleet.

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F. Optimization of the Vehicle - Fuel - Refinery System, R. F. Wilson, W. T. Tierney, API 41st Midyear Meeting, Los Angeles, California, May 10-13, 1976, Preprint No. 16-76.

G. United Parcel Service Applies Texaco Stratified Charge Engine Technology to Power Parcel Delivery Vans -- Progress Report, J. M. Lewis, W. T. Tierney, SAE Truck Meeting, King-of-Prussia, Pennsylvania, November 10-13, 1980, Paper No. 801429.

(Note: The references cited above may be found in subcommittee files.)

## II. History of the Development of the Texaco Controlled-Combustion System (TCCS) Stratified Charge Engine Concept

The concept of the TCCS was originated by Mr. Everett M. Barber at Texaco's Beacon Research Laboratories during the early 1940's. It was an outgrowth of fundamental engine combustion studies seeking to establish a measurement procedure that would correlate with the spontaneous combustion characteristics of fuels. This is represented by octane number rating for gasolines which is a a fuel's resistance to knock and diesel fuel cetane numbers which characterize its ease of spontaneous ignition.

Engine design was developed that would permit operation without the requirement for either octane or cetane number of the fuel. An engine was modified to incorporate the features. As soon as the proper location for the fuel spray relative to the spark plug was defined, it was possible to demonstrate the feasibility of the concept. This was done by operating on the reference fuels that define the octane and cetane scales. It also was possible to supercharge the engine to high levels of output without octane requrement. The detail of this sequence of experiments is described in reference A of the Bibliography of Section I.

Having achieved reliable and repeatable engine operation, Texaco pursued the development further. This work was expanded in the late 1940's at which time consultants were retained to assist in pursuing the best course for implementing and optimizing the combustion system. They were: Professor C. Fayette Taylor of MIT as a general engine consultant, Professor H. A. Everett of Pennsylvania State College as a thermodynamacist, Professor Kalman DeJuhasz also of Penn State for fuel injection system design and evaluation, and Professor Wolfgang E. Meyer also of Penn State for combustion studies utilizing the photographic and other techniques available at the time. The results of some of these studies are outlined in reference B which includes photographs showing that the combustion is, in fact, stratified. In addition to this, the results of the study of the rate of fuel energy supplied to the combustion system, and the rate of heat release in the combustion chamber are similar showing that the process is, indeed, injection rate controlled further confirming charge stratification.

Reference B also lists the wide range of engine sizes that were studied either under the impetus of Texaco's own programs or in response to inquiries from and agreements with various engine and vehicle manufacturers.

During the 1960's two military programs were contracted to Texaco. One was for a development of a small air cooled, generator-drive engine for the U.S. Army, Corps of Engineers under the sponsorship of the Engineering Research and Development Laboratory of Fort Belvoir, Virginia. The result of this work is described in the technical paper of reference C.

The second Army project undertaken was in response to a request for quotation for stratified charge engines capable of multifuel operation in an Army M-151 "jeep" vehicle. The details of both phases of this project are discussed in references D and E of the Bibliography. The success of the M151 project led to a follow-on contract with White Engines Inc. for the development of a new four cylinder engine. Data on the L163S engine resulting from this program are reported in Appendix A of reference number G of the Bibliography. Further Army financial support of the TCCS development in 1978 discontinued.

In order to further evaluate these engines, several engines were reassigned to the U.S. Postal Service. An evaluation program is currently in progress. The Department of Energy, Bartlesville Laboratory, arranged for the installation of a 163 engine in a 1973 AMC Gremlin X body. The test results of this program are also reported in Appendix A of reference G. This Gremlin test vehicle has been loaned to the Canadian Government where tests in cold weather operation on a wide range of fuels are currently underway.

In 1978 United Parcel Service (UPS) investigated the potential of the TCCS for the improvement of the fuel economy of their package delivery vans. The size of this fleet, about 35,000, constitutes the largest such operation in the world. Past experiments by UPS with diesel engines in their van service did not prove satisfactory. The detail of this background is discussed in reference G.

A contract was signed between UPS and Texaco in April, 1978 for the conversion of one of the standard gasoline engines of the UPS van fleet, the six cylinder General Motors 292 (292 $in^3$) to the TCCS.

## III SUMMARY OF MAJOR STUDY AREAS IN THE DEVELOPMENT OF TCCS ENGINES

The following subsystems of the TCCS engine required specific engine development effort.

### A-AIR INTAKE PORT AND VALVE

Since the TCCS engine requires a swirling air mass in the engine cylinder it is necessary that the intake port and valve be designed so as to provide the necessary directional air flow into the cylinder at high levels of efficiency.

Early work on the process could be carried forward utilizing a standard intake port and a so-called shrouded valve. The shroud is a vertical, cylindrical surface either fastened to the valve or otherwise so arranged as to restrict the flow of the air from the valve when it is lifted from its seat in such a manner that the air is all directed into the open area of the flow passage. This technique permitted substantial development of the engine concepts. It was felt that, since many commercially available engines had specially designed intake ports and valves for efficient creation of air swirl, the general design information would be available from appropriate sources so that an efficient port could be made available for fully developed TCCS engines. Search of the literature and discussion with many manufacturers showed that the design of such ports was indeed a proprietary area with each of the specific engine manufacturers.

An air flow testing facility was established at Beacon Laboratories so that the important parameters required to study these air flow concepts could be evaluated. In the course of this work, more efficient shrouded valve systems were developed and the initial work on the specific definition of swirl creating ports for the Texaco requirement was undertaken.

At the time of the design of the TCCS L-163 4-cylinder 163 cubic inch engine for the U.S. Army M151 or Jeep vehicle by White Engines Incorporated, it was deemed desirable to actually provide the most efficient valve design possible for this project in order to insure its success. Under a contract awarded to Ricardo Engineers of England, a port design was developed based on their background in the development of such ports for some of the engines that they had worked with over the years. The basic port that was a result of this effort was further refined at Beacon to specifically fit the dimensional requirements of the White Engine design.

The basic port design was again modified to adapt it to the configurational requirements of the United Parcel Service 292 SC program. This was the conversion of the General Motors, 292 cubic inch displacement, 6-cylinder gasoline engine to TCCS for the United Parcel Service program.

Both of these port designs have produced results predicted by the laboratory flow studies.

## B-INTAKE AND EXHAUST VALVE TIMING AND CAMSHAFT DESIGN

Utilizing the efficient valve and intake port design development mentioned above, it is necessary that the flow area through which the intake air is delivered to the engine be made available at a rate that makes it possible for the optimum amount of air to be delivered to the engine cylinder. Since the efficiency with which this air issuing from the open portion of the intake valve as it leaves the seat of the intake port can vary as the valve opening increases, it is necessary that both this and the open flow area be jointly considered in determining the valve timing from the standpoint of assuring maximum intake air delivery to the engine.

Since the crown or top of the piston of a TCCS engine comes very close to the flat bottom of the cylinder head which contains the intake and exhaust valves and ports, the valve timing must be such that the valves do not interfere with the piston during the top part of its motion in engine operation.

The combination of these requirements on the timing and rate of movement of both the intake and the exhaust valve must be considered in determining the actual timing sequence of the valves. Another fact that must be considered is the rate at which the mass of the intake system, which includes the valves, its springs, and a mechanism utilized to move the valve in consonance with the shape of the cam in the engine must be considered in order to assure that the valve motion is under control at all times and that the parts are not overly stressed in order to insure long engine life.

Generally speaking, these criteria must be well defined in Texaco design recommendations to engine builders. However various other factors do require that trade offs be made at times in order to permit the proper design of the total engine.

Single cylinder engine test stands have been equipped to study some of the key parameters necessary to provide acceptable designs of the intake system mechanisms.

## C-FUEL INJECTION SYSTEM

The TCCS is a direct cylinder-injected engine. The fuel injection system delivers the fuel to a high pressure injector. A diesel engine type injection system is utilized. However, many of the requirements for the TCCS differ from those conventionally used in a diesel. The key differences in this respect are that the duration of injection at maximum fuel delivery quantity for a TCCS engine is considerably longer in engine crank angle degrees than that normally used for the diesel. Secondly, the fuel injection pressures for the TCCS engines are usually lower than those of the diesel. Since the TCCS is a multifuel engine, the system must handle light fuels such as gasolines as well as heavier fuels.

These stated differences have required that the parameters of typical fuel injection systems be studied in order to obtain the appropriate rate of fuel injection and that the specifications for systems for development engines can be presented to the fuel injection equipment manufacturers. Over the years, a wide range of fuel injection systems have been studied and general parameters developed.

By far the bulk of the work since the 1950's has been carried forward with the cooperation of Stanadyne of Hartford, Connecticut. Their fuel injection system has many unique features that make it desirable for the TCCS. Among these are the small size of the fuel injectors, the low cost of the pump and its compact size.

In the course of developing TCCS engines capable of running on gasoline it was necessary to study the metallurgy of the pump and make changes that have provided great improvements in the durability of the overall system.

Another development that has been implemented is the modification of the fuel injector so that it can be utilized as an electrical trigger for the ignition system. This simplifies the requirement of causing the mechanically controlled ignition system normally available to match the hydraulic characteristics inherent in the fuel injection system.

## D-IGNITION SYSTEM

The initial studies in the development of the TCCS utilized conventional automotive ignition systems. Since the TCCS combustion concept does not limit compression ratio to the available octane quality of the fuel, it was possible to increase the compression ratio to the range of 10 to 13 to 1 which is considered to be the desired range for optimizing the efficiency of the engine. At these high cylinder pressure conditions some difficulty was experienced with the conventional automotive type ignition system design. The application of supercharging to the TCCS engine, which is a viable option, further increased the difficulty encountered with conventional ignition systems.

As a result of these difficulties, consideration was given to the potential for the development of a new high energy system that would better satisfy the TCCS requirements. In the 1960's a project was undertaken at one of Texaco's Research

Laboratories to develop such a system. The result of our work was an oscillating system. It provides an alternating current to the spark plug through the application of electronic control systems to reverse the polarity of the conventional direct current supply provided by an automotive battery. Over the years the capability of the electronic control system has been exploited to the point were many control options are now available for the modification of this system to satisfy particular engine application requirements. The general detail of the system was described in a paper before a meeting of the Society of Automotive Engineer's in 1975.*

The advent of the United Parcel Service project and the potential for the extended application of the White Engines 163 TCCS engine has resulted in interest on the part of Echlin Manufacturing Company in the production of the Texaco Ingnition System referred to as TTIS.

Initial prototype units representing the commercial configuration have been prepared and are currently being testing in the on-going engine programs.

## E-EMISSION CONTROL

Since the enactment of the Clean Air Act Amendments of 1970, it has become necessary to consider various levels of emission controls for TCCS engine projects.

The first effort in which this was encountered was during the period of the development of a TCCS conversion of the U.S. Army 141 cubic inch 4-cylinder gasoline engine of the M151 so-called "Jeep" vehicle. The contract with the U.S. Army, Tank and Automotive Command Headquarters of Warren, Michigan, was for the modificaton of the engine to TCCS for operation on a wide range of fuels at good fuel economy. Multifuel capability was considered important since it would enable a military vehicle to operate on indigenous fuels in a foreign theater of operation. This combined with the good fuel economy would greatly simplify the logistical problems of providing fuel to a combat zone where shipments into the area frequently exceed 80 percent of all material delivered.

The first phase of the project was to equal the power output of the standard gasoline engine. This requirement was met at substantially improved fuel economy as detailed in our 1972 technical paper before the SAE. This is reference D in the Bibliography section.

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*Texaco Ignition System - A proven New Concept for Automotive Engines, R. E. Canup, SAE Congress and Exposition, February 24-28, 1975, Paper No. 750347.

During the latter quarter of 1973 the project was extended to include the emmision control of the engine to meet the severe standards (0.41 HC, 3.4 CO, $NO_x$ 0.4 grams per mile) proposed in response to th Clean Air Act Amendments of 1970. The results of this effort were also reported to the SAE and covered in the paper of 1974 listed as reference E in the Bibliography. The net effect of this work was to actually meet the stated standards, but this was at the sacrifice of both engine performance and fuel economy. The engine, under these stringent controls, did equal the fuel economy of the uncontrolled gasoline engine normally installed in the vehicle. It should be noted that the major portion of the penalty was associated with the control of $NO_x$ to 0.4 grams per mile. This level has not been imposed by regulation as yet.

Subsequently, the Army contracted for a TCCS engine that was specifically designed for operation on the process rather than the conversion of an existing gasoline engine. Since this was to require complete engine design and manufacture, the contract was awarded to White Engines Incorporated with Texaco as a subcontractor. The end result of this project was the development of the L163 S engine which is an engine that is approximately the same dimensions as the 141 cubic inch gasoline engine. It weighed about 30 pounds more because of the need for the additional gearing to drive the fuel injection pump and the weight of the injection equipment itself. No modification was required to install this engine in the M151 vehicle. Emission control technology had to be applied to the unit so that the vehicle could meet the 1979 light duty truck emission cycle standards of 1.7 HC, 18 CO, and 2.3 NOx grams per mile. The satisfaction of these requirements is reported in Appendix A of reference G of the paper presented before the Society of Automotive Engineers in 1980.

Following this testing program the Department of Energy obtained one of these L163 S engines and had it installed in an AMC Gremlin X 1973 model car body by White Engines Incorporated. This vehicle was utilized by the Bartlesville, Oklahoma Laboratory of the Department of Energy to determine the emission levels under the passenger car test procedure. This effort was further extended to determine the fuel versatility of the engine. Operation was demonstrated on unleaded gasoline, a simulated shale derived gasoline, wide boiling range fuels and diesel fuel. Ethanol and methanol were also used, however, emissions were not measured because of uncertainty relative to the applicability of the standard instruments when measuring alcohol fuel combustion products. The results of this work will be included in White Engine's submittal. Following this, the Canadian Government requested that the DOE vehicle be provided to them on loan so that they might conduct similar testing under their cooler weather conditions. It was shipped in March of 1980 and is currently undergoing a series of tests. It is intended to conduct an extensive program on gasoline, wide boiling range fuel and methanol.

It would appear that emission control for the Canadian requirement will not be necessary since their standards of 2.5 HC, 25 CO, 3.1 NOx grams per mile will be easily met by the engine under all operating conditions.

## IV SUMMARY OF STUDIES RELATING TO THE CONSERVATION OF TRANSPORTATION FUEL RESOURCES THROUGH THE APPLICATION OF FUEL EFFICIENT ENGINES IN THE NATION'S MOTOR VEHICLE FLEET.

Since the application of the internal combustion engine to vehicular transportation there has been a continuing desire to improve the fuel efficiency of the engine. In the carburetted gasoline engine this had been accomplished largely through increases in compression ratio which manifests itself in a requirement for higher octane fuels. Octane is the fuel specification that indicates the resistance of the fuel to spontaneous ignition or knock. In the case of the diesel engine, which operates on compression ignition, the ability to reduce engine weight and increase engine speed has been dependent upon the operation of the engine at lower compression ratios. In order to do this, the diesel fuel must have a lowered resistance to spontaneous ignition. This requires higher cetane number specification fuels.

Over the years the refining industry has been able to satisfy these changing demands of the motoring public. Octane was increased efficiently through the use of lead compounds as additives to the gasoline while cetane increase was dependent largely upon the ability of the petroleum industry to segregate the naturally occuring higher cetane products for use in these engines.

The restriction of lead additives in gasoline in order to satisfy the lead phase down regulations and the elimination of lead from those gasolines to be utilized in catalyst equipped cars resulted in the need for more extensive processing in the petroleum refinery. This required that an increasing amount of energy be consumed in the refinery to supply its process needs.

It was necessary that engines be designed at lower compression ratios because lead-free fuels could not be supplied with as high an octane number as the previous leaded gasolines. The overall effect of this, starting with the 1975 cars, was an approximate 7 percent loss in fuel economy or engine efficiency of the engines relative to those operated on leaded, higher octane fuels.

The imposition of fuel economy improvement standards in the Clean Air Act Amendments of 1977 resulted in two developments. The first was a reduction in vehicle and engine size. The second was modification in engine design including compression ratio increase.

There is a spread in the octane number of the fuels in the marketplace because crude type and process unit capability vary among refiners. In the event that a customer's engine encountered knocking an effort was made to find a more satisfactory fuel. This created market pressure which caused fuel refiners to increase the octane of their fuel for customer satisfaction reasons. The net affect of this was to increase the average octane number of the unleaded gasoline in the United States.

To determine the impact of these various fuel quality changes on its operation, Texaco had initiated a series of studies. As a basis for the studies, a 100,000 barrel per day refinery was assumed with processes representing the average of the U.S. petroleum industry in 1974-5. A crude slate combining a mixture of imported as well as domestic crudes was selected to approximate the average of a mixture of all crudes then being processed in the U.S. The product slate for the model refinery represented a pro rata share of the total U.S. market. This was based on the ratio of the 100,000 barrel per day capacity to the total refining industry capacity at that time (12.5 million barrels per day). In essence, the model refinery was programmed to supply 1/125th of the total U.S. market for all products.

The product slate had to include the study of the transportation fuel requirement on the basis of the several engine types including TCCS. In each of four cases, it was assumed that the introduction of an engine type would displace to the maximum possible all engines in its particular category of operation. The total U.S. vehicle fleet mileage was found to be 4.3 billion road miles per day. Of the number 2 fuel oil which is utilized both as diesel fuel and home heating oil, 43 percent was required for the then existing diesel fleet. One 125th of this volume was determined to be 10,131 barrels per day which was established as the diesel fuel requirement for the simulated refinery. The amount of gasoline was based on an average fuel economy of 12.05 miles per gallon for the leaded fuel vehicles then on the road. The fuel economy of the gasoline engine operating on 96 research octane fuel was used as the base case against which the other cases were compared. Diesel engines were assumed to have a 30 percent fuel economy improvement over the gasoline engine and the TCCS a similar amount based on tests conducted by outside laboratories. The full detail of this is contained in the 1975 paper before the Society of Automotive Engineers listed as reference G.

The second case assumed that all gasoline engines would be replaced by engines requiring catalytic converters and operating on unleaded 91 research octane fuel. Studies had shown that the reduced compression ratio required for satisfactory operation on such a fuel imposed a 7 percent fuel economy penalty relative to the leaded fuel engines.

The third case assumed that the vehicle fleet would contain a maximum number of diesel engines based on the maximum quantity of diesel fuel that could be supplied by the model refinery taking advantage of current refining technology.

The fourth case is one in which all gasoline engines are replaced by a TCCS type engine capable of operating on a fuel without octane or cetane specification. Another stipulation was that the fuel's boiling range was stated to be between 100 and 650° F (38-93°C). The latest of these studies is summarized in Appendix B of the SAE paper of reference G.

The bar graph of reference G clearly shows the petroleum conservation advantage of the TCCS vehicle fuel efficiency with its ability to operate on a fuel requiring reduced refinery processing energy. This study demonstrates the importance of stressing "miles per barrel of crude" rather than "miles per gallon of fuel".

Mr. OTTINGER. Next, Mr. Holtgreive.

## STATEMENT OF ROBERT J. HOLTGREIVE

Mr. HOLTGREIVE. Mr. Chairman, members of the committee, I appreciate this opportunity to appear before you today and discuss the direct injected stratified charge combustion system and its related programs at White Engines.

I am Robert Holtgreive, the executive vice president. I have with me today also Gary Kandel, the project engineer on the stratified charge engine work that we are doing at our facilities in Canton, Ohio.

We manufacture gasoline, natural gas, diesel, and multifuel engines for the industrial market and for military vehicles.

White Engines and I personally have been involved with the Texaco controlled combustion system over the past 12 years, starting with the fabrication of demonstration engines for Texaco in 1968.

Our major efforts were started in 1973 when we were awarded a development contract by the Army Tank-Automotive Command for a new liquified cooled in-line stratified 183-cubic-inch stratified charge engine with multifuel capabilities.

The engine was slated for a new one-half ton tactical vehicle having multifuel capability using the Texaco controlled combustion system.

Engines were designed, manufactured, dynamometer tested and installed in test vehicles within a 2-year period. Limited testing was completed at Texaco and Southwest Research Institute. Unfortunately, the total vehicle/engine program was discontinued when the Army cancelled the new vehicle requirement.

The Government decided at that time to stay with the M–151 one-quarter ton vehicle. White Engines proposed at that time incorporating the TCCS into White's standard commercial model G–1600 gasoline engine as a drop-in replacement with improved fuel economy and multifuel capability over the standard M–151 vehicle engine.

The basic G–1600 engine provided a production tooling base, high reliability with proven components which minimized the time and risk when applying the TCCS. The U.S. Army accepted White's proposal and designated the engine as the L–163S. That stands for liquid cooled 163-cubic-inch stratified.

Maximum effort was successfully applied on this contract to eliminate all components and parts which were not consistent with high volume production or advanced technology. Also, product improvements developed on the previous program were incorporated into the L–163S engine.

The development program was successfully completed and included approximately 24 months of vehicle testing at Southwest Research Institute. However, with limited future vehicle production requirements and the proposed plan by the U.S. Army to use commercial vehicles, the development program was discontinued in 1979.

Because of the success experienced on this contract and the recognized potential, White Engines elected to continue the development of the L–163S engine for the commercial market.

During the above mentioned contract, various other Government agencies became directly involved in testing the L–163S engine on dynamometers, as well as in vehicles. These included the Department of Energy's Bartlesville Energy Technology Center and the U.S. Post Office.

The U.S. Post Office has received four L–163S engines for test and evaluation in one-quarter ton postal vehicles. One of these vehicles has been on delivery service in Salt Lake City, Utah for approximately 24 months, operating on diesel fuel. A fuel economy improvement of approximately 60 percent is being realized when compared to the standard vehicle with a gasoline engine.

Another L–163S vehicle has been optimized on gasoline and is currently undergoing tests at the Post Office Research Department in Rockville, Md. The remaining two engine/vehicle installations have just recently been completed by the Post Office.

An L–163S engine was installed in a 1977 Gremlin by White Engines, optimized by Texaco, and tested by the Department of Energy on various fuels, including gasoline, wide boiling range fuels, methanol, and ethanol. A complete report of this work is attached. [See p. 29.]

This same Gremlin vehicle is now being evaluated by Transport Canada and the Canadian Ministry of Transportation and Communications in Downsview, Ontario. Preliminary test data from Transport Canada is also attached which basically confirms some of the data published in the Bartlesville report.

When considering the flexibility of the TCCS system, I would like to make the following comments with regard to adaptation of the system, fuel capability and engine applications.

Our development has demonstrated that the direct injected stratified charge system can successfully be adapted to current production spark ignition engines. The adaptation basically consists of a new cylinder head assembly incorporating a high swirl intake port and provisions to accept the combination of a spark plug and injection nozzle. A cup type piston and a provision to drive the fuel injection pump are also required.

The latest vehicle testing has demonstrated the flexibility of the engine to operate on most all currently available or proposed liquid transportation fuels. Minor adjustments may be necessary to maintain optimum performance when switching from fuel to fuel, but are not necessary to maintain continued vehicle operation.

Preliminary performance data indicates that the L–163S engine will successfully start and operate at room ambient temperatures on ethanol and methanol. No endurance testing has been conducted to date on either ethanol or methanol.

The performance and design characteristics of the L–163S engine makes it compatible with and an excellent replacement for existing vehicle and industrial applications which now use conventional internal combustion gas or diesel engines of this comparable size.

The various development programs have provided White Engines, Inc., with the opportunity to evaluate the reliability of the TCCS componentry along with the basic engine when operating on unleaded gasoline and diesel fuels.

As on all new developments, we experienced reliability problems on some newly designed components and/or systems.

The technology to successfully operate a standard diesel fuel injection system on unleaded gasoline was developed on the LIS–183 military contract coordinated by White Engines. Comparable studies will more than likely be required for operation on methanol and/or ethanol.

Since the start of the first development contract, the reliability of the required high energy ignition system has been improved substantially through system optimization and improved manufacturing techniques.

The basic engine has proven to be reliable, as expected. However, premature camshaft wear was found during early testing and required additional development for some duty cycles. Latest testing indicates that this problem has been resolved.

Limited emission studies were conducted throughout the previously mentioned programs. Tests completed indicated the engine is capable of being certified, depending on the type of fuel and the amount of conventional emission equipment used, such as catalytic converters, exhaust gas recirculation systems, a fuel pump servo mechanism, and so forth.

The advantages of this engine design from the standpoint of a manufacturer with regard to production and marketing are as follows:

White Engines feels that ths engine has an advantage because its current production tooling technology can be utilized to mass produce this engine.

Reliability of the basic engine design is unquestioned since it incorporates proven production internal combustion engine technology.

Current engine accessories such as alternator, starter, cooling system and fuel injection system are compatible with the basic engine design.

All other components in the engine, including the current valve train, seals and gaskets, are of conventional design.

White Engines, Inc., feels that this engine will be less expensive to manufacture—dollars/per horsepower—than other advanced all fuel engine concepts currently being considered; that is, turbines, Stirling.

The marketing advantages include all fuel capability, improved fuel economy, excellent cold starting and warmup on diesel fuel, and light weight.

The expected advantages to be realized when operating the L-163S engine on methanol include:

Good cold starting and operating characteristics due to direct injected fuel and postive spark ignition, eliminating heated manifolds and other systems now required to aid starting and maintain fuel atomization; and

Injecting and retaining the fuel in the combustion cup should greatly reduce the upper cylinder wear problems evident in some prototype carbureted engines currently on test with methanol.

White Engines recommends additional fleet testing based on the successful vehicle testing completed to date by Southwest Research Institute, U.S. Post Office, Department of Energy, Transport Canada, and the Canadian Ministry of Transportation and Communications.

The vehicle selected for fleet testing must be compatible with the engine compartment size and horsepower output of the L-163S engine. The fleet size and application engineering required will directly determine program schedule and corresponding cost.

It is suggested that the fleet testing be initiated using gasoline and/or gasoline blends and wide boiling range fuels for baseline tests. While baseline tests are being completed, Texaco, Stanadyne, and White Engines would complete basic studies on performance and endurance with respect to methanol and methanol blends. Any modifications or advanced technologies determined for successful methanol operation would then be applied to the active fleet.

In closing, I would like to emphasize that White Engines is bullish on the future of the direct injected stratified charge engine because of its all fuel appetite and conventional methods of manufacturing.

We are receptive to applying our engine technologies to advance the engine that can bridge the requirements to move from today's fuels to fuels of the future.

This concludes my testimony, Mr. Chairman. I will be happy to respond to questions.

[Testimony resumes on p. 42.]

[Attachment to Mr. Holtgreive's prepared statement follows:]

September 23, 1980

# PERFORMANCE EVALUATION OF A STRATIFIED-CHARGE ENGINE POWERED AUTOMOBILE

by

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## ABSTRACT

An experimental study was conducted to assess the performance of an advanced technology White Engines, Inc., stratified-charge engine installed in a late-model vehicle. Chassis dynamometer tests were made to determine the influences of fuel characteristics and ambient temperature on fuel economy. The fuels used were: a regular unleaded gasoline, a low octane oil shale-derived gasoline, and a gasoline/diesel blend representative of a broadcut fuel. Alcohol fuels were also used in limited experiments. The vehicle was tested at temperatures of 20°, 50°, 75°, and 100° F using the Federal Test Procedure and the highway fuel economy test. Vehicle economy was virtually unchanged by fuel differences. Ambient temperature was found to have a significant effect on fuel economy, while emissions, except for unburned hydrocarbons, displayed minimal temperature sensitivity.

## INTRODUCTION

The present concern about dwindling petroleum reserves in future years has led to much activity in the search for, and technical assessment of, fuel options for use in transportation. The options include alcohols and refined liquids derived from coal and oil shale, as well as the possibility of extending current petroleum supplies through utilization of wide boiling range fuels. Such options are currently being viewed as future alternatives or supplements for automotive fuels. An engine that has exhibited the capability of being compatible with a wide range of fuels without major modification or adjustment is the White/Texaco Controlled-Combustion System (TCCS) stratified-charge design (1-4)*. The present configuration of this engine design is a result of more than 30 years development. In addition to exhibiting a broad fuel tolerance, previous work with this engine has shown promising fuel economy much like that of a diesel engine.

It was the intent of this study to assess the performance of this advanced technology stratified-charge engine installed in a late-model automobile. The emphasis of this program was to examine fuel economy and exhaust emission characteristics of the vehicle as affected by different fuels and varying ambient temperatures. Fuels used in the study included

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*Underlined numbers in parentheses refer to References at end of paper.

a lead-free gasoline, a gasoline/diesel fuel blend (approximating a wide boiling range or broadcut fuel), and a low octane gasoline derived from shale oil. A limited number of vehicle tests were also performed using alcohol fuels. The tests were conducted at the Bartlesville (Okla.) Energy Technology Center (BETC).

## TEST PROGRAM

### Engine/Vehicle

The engine/vehicle system used in this evaluation is a result of installation by White Engines, Inc. of a White Model L-163S engine, utilizing the Texaco, Inc. patented TCCS, in a 1977 American Motors Corp. (AMC) Gremlin X supplied by AMC (5).

Table 1 contains specifications of the L-163S/TCCS engine. This stratified-charge engine is a water cooled, 4-stroke cycle, direct-injection design utilizing controlled fuel injection and air swirl in conjunction with positive spark control. As with diesel engines, the L-163S operates unthrottled, but the positive spark control negates the need for the high compression ratios required by diesel engines. Fuel injection is controlled by a Roosa Master DB-2-427 pump with torque control. The ignition system is a high energy type with multistrike capability during the spark event. Texaco suggests that while the engines are relatively insensitive to minor changes in injection and ignition timings, optimum timing adjustments are necessary for operation with alternative fuels in order to achieve best operation with respect to fuel economy, emissions, and driveability. Table 2 lists the values of injection and ignition timings for unleaded gasoline and the gasoline/diesel fuel blend as recommended by Texaco for knock-free operation. Timing adjustments used for the shale oil derived fuel were the same as those recommended for the unleaded gasoline. The engine was equipped with an exhaust gas recirculation (EGR) system of Texaco design, utilizing an auxiliary vacuum system.

As delivered to BETC, the 1977 Gremlin was equipped with:

- 4-speed manual transmission,
- 2.73:1 limited slip rear axle,
- power steering,
- vacuum assisted brakes,
- air conditioning, and
- DR-78-14 radial ply tires.

The vehicle exhaust included an Englehard PTX-5D catalytic converter in addition to the standard exhaust system normally used with AMC 6-cylinder engines. Vehicle curb weight was approximately 2,800 lb. The Gremlin was tested at an inertia weight of 2,750 lb. All tests were conducted without air conditioning.

## Test Fuels

Three fuels were used in the primary test series: a 91 octane, unleaded gasoline; a low-octane (80 RON) shale-derived gasoline; and a blend of 75 pct gasoline (91 octane) and 25 pct 2-D diesel fuel. The gasoline/diesel fuel blend simulated a wide boiling range fuel. Table 3 gives fuel inspection data for the reference and shale-derived gasolines and for the diesel fuel used in the blend. A brief examination of ethanol and methanol as fuels for the vehicle was also conducted.

## Test Procedures

The L-163S powered Gremlin was tested according to the Federal Test Procedure (FTP) and highway fuel economy test (HFET) as prescribed by the Environmental Protection Agency (EPA). Data were obtained with the three fuels at an ambient temperature of 75° F. Results were also gathered using the unleaded gasoline and the gasoline/diesel blend at ambient test temperatures of 20°, 50°, 75°, and 100° F. Hot start FTP data were obtained at 75° F using both ethanol and methanol as fuels. Additional data were taken to examine economy and emissions sensitivity to variations in spark and injection timing.

Vehicle experiments were conducted using a climate controlled chassis dynamometer--Clayton Model ECE-50-120 with direct drive inertia system and road load power control.

The exhaust gas analytical techniques used were as follows:

1. Carbon dioxide and carbon monoxide (CO) by nondispersive infrared.

2. Unburned hydrocarbon (HC) by a heated flame ionization detector (FID).

3. Oxides of nitrogen ($NO_X$) by chemiluminescence.

4. Aldehydes by the MBTH procedure.

Particulate mass emissions were obtained by dilution tunnel sampling. Fuel economy was calculated by the carbon balance method. In cases of replicate experiments, results presented are averages.

# RESULTS AND DISCUSSION

## Fuel Effects

Fuel economy results from tests at normal ambient temperature (75° F) using the three fossil fuels are presented in table 4. While some variability exists in urban and highway economy figures, the composite fuel economy differences exhibited less than a 3 pct spread from lowest to highest. The economy value presented for the highway cycle using the shale-derived gasoline, while significantly higher than for the other fuels, is based on a single test and may not be representative.

Exhaust emissions (table 5) show more definite influences due to fuel type. The FTP CO emission rate for unleaded gasoline was 2.1 gpm--well below values for the other two fuels--with the gasoline/diesel blend highest at 3.5 gpm. Unburned HC for the blend were also highest at 1.6 gpm compared to about 1.0 gpm for both the unleaded and shale-derived gasolines. Measurements of $NO_X$ indicate an opposite trend with the gasoline/diesel blend and gasoline exhibiting rates of 1.4 and 1.7 gpm, respectively, while the shale-derived fuel registered about 2.3 gpm. The high $NO_X$ values associated with use of the shale-derived gasoline may be due to reaction of fuel-bound nitrogen.

Fuel effects on particulate emissions were similar to those of CO. The blended fuel displayed the highest mass emission rate at 0.18 gpm. This value, while twice that seen for the unleaded gasoline, is still at a level below any proposed particulate standards. Aldehyde levels were minimal and not significantly affected by fuel character.

## Temperature Effects

### Unleaded Gasoline

Temperature effects using unleaded gasoline are presented in table 6. Using the 75° F test results as a baseline for comparison with other test temperatures, fuel economy was essentially unchanged at 50° F for both urban and highway cycles. The largest FTP temperature effect was at 20° F with a 10 pct decrease in economy. An increase of about 6 pct in consumption was shown for the highway cycle with an ambient temperature change from 75° F to 20° F. At 100° F, fuel economy increased over 75° F values for both FTP and HFET cycles by about 5 pct and 3 pct, respectively. The increase in FTP fuel use at the lowest temperature is attributable to the cold-transient phase of the cycle. Emissions of CO, $NO_X$, and particulates show no dependence on temperature while HC rates show a notable increase only at 20° F. Aldehyde emissions remained essentially unchanged except at 100° F where a slight decrease was exhibited.

### Gasoline/Diesel Blend

Data obtained at 20° F with the gasoline/diesel fuel show unexpectedly high fuel economy, particularly in the highway cycle (table 7). These results were based on a single experiment and, though included for purposes of information, should not be considered representative. Urban economy was decreased at 50° F by about 7 pct relative to operation at normal ambient temperature and remained essentially constant with a change from 75° to 100° F. As in the case of unleaded gasoline usage, fuel economies were similar at 50° and 75° F, and about 4 pct higher at 100° F.

The FTP CO and HC emissions showed a marked increase at 50° F, due to higher emission rates occurring in the cold transient portion of the driving cycle. Somewhat higher CO and HC results were also seen at 100° F. Particulate and aldehyde emissions exhibited little sensitivity to temperature effects with the gasoline/diesel blend used for fuel.

## Effect of Catalyst Replacement

A review of the emissions data presented thus far led Texaco to the conclusion that the primary catalyst, an Englehard PTX-5D, was no longer effective. They felt that the catalyst failure could have resulted from excessive catalyst temperatures incurred during vehicle shipment to BETC. In order to investigate these suspicions, further experiments were conducted with a replacement oxidation catalyst installed. Comparisons of reference gasoline test results obtained before and after catalyst replacement are presented in table 8. Economy improvements with the new catalyst ranged from 7 pct for the urban cycle to about 5 pct for the highway test. Emission rates of CO were substantially reduced from 2.0 to 0.5 gpm. Catalyst replacement also influenced HC results positively, but to a lesser degree. Levels of $NO_X$ emission, however, were increased substantially. This change in $NO_X$ rate may be attributable to either minor variation in spark and ignition timing adjustments or a malfunction of the EGR system. Particulate emissions remained essentially the same at less than 0.1 gpm. Replicate tests confirmed these trends; substantiating Texaco suspicions concerning the original catalyst. It is reasonable to assume that the positive trends obtained with the catalyst replacement might also be realized with the other fuels.

## Alcohol Fuels

Comparisons of fuel economy and emissions data obtained from hot-start FTP tests, using unleaded gasoline, denatured ethanol, and methanol as fuels, are shown in table 9. These experiments were limited and intended only to assess the feasibility of utilizing alcohols with this engine design. Ignition and injection timing settings were the same as recommended for gasoline. No changes were made to the fuel metering system to compensate for the decreased energy contents of the alcohols. These tests were conducted after oxidation catalyst replacement.

Hot-start energy economy values were determined using nominal fuel energy values of 1.15 ($10^5$), 0.76 ($10^5$), and 0.58 ($10^5$) Btu/gal for unleaded gasoline, ethanol, and methanol, respectively. Energy economy results were of similar magnitude for all three fuels with methanol economy about 5 pct less than that obtained using ethanol and unleaded gasoline.

The CO emission rates with the alcohol fuels at 0.2 gpm were markedly lower than the results for gasoline. Hydrocarbon emissions with the engine operating on ethanol were about twice those found with gasoline and methanol. Hydrocarbon results were not corrected for FID response characteristics for the alcohols. Instrumentation problems precluded obtaining $NO_X$ information.

## Effects of Timing Adjustments

Table 10 shows the influence of changing ignition/injection timing settings from nominal values used for the gasoline fuels to settings recommended by Texaco for the gasoline/diesel blend. With unleaded gasoline, composite urban/highway fuel economy was unaffected. Emission levels were generally decreased by the change--with $NO_X$ levels most significantly lowered from 2.4 to 1.7 gpm. Similar timing adjustments made while operating with the low octane shale-derived gasoline produced a slight decrease in economy. Carbon monoxide levels were unchanged, while HC rates increased somewhat. Oxides of nitrogen emissions were lowered in magnitude; similar to the results for $NO_X$ using unleaded gasoline. The timing changes produced substantial increases in particulate emissions with shale-derived gasoline use. In general particulate emissions from the unleaded gasoline tests were lower than those found in experiments with the other fuels. It should be noted that the injection pump torque control was adjusted for use with unleaded gasoline. Therefore, these differences in particulate levels may be attributable to control effects in addition to changes in fuel characteristics.

## SUMMARY


o Tests of the White/TCCS engine-powered Gremlin showed no significant changes in EPA composite urban/highway economies over wide variations in fuels.

o Exhaust emissions with the gasoline/diesel fuel and shale-derived gasoline were generally higher than those obtained using reference unleaded gasoline.

o Exhaust emission rates with the vehicle operating on unleaded gasoline compare to EPA standards as follows:

- -- Carbon monoxide rates were much lower than the 3.4 gpm requirement for 1981.
- -- Hydrocarbon and $NO_X$ levels were about double the 1981 standards of 0.41 and 1.0 gpm, respectively.
- -- Particulate mass emissions (for all fuels) were well below the 1982 0.6 gpm required level and the 1985 standard of 0.2 gpm.

No efforts were made during the study to optimize engine performance with respect to emissions. Changes in the ignition/injection timing settings, fuel metering control, and EGR could possibly result in lower exhaust emissions of HC and $NO_X$.

o Fuel economy displayed a temperature dependence similar to trends normally observed with diesel engine-powered vehicles. Temperature effects on exhaust emissions were generally small.

o Over all, the vehicle exhibited not only good fuel tolerance, but good economy for a vehicle in this weight category.


## REFERENCES


1. Bechtold, R. L. Performance, Emissions, and Fuel Consumption of the White L-163-S Stratified-Charge Engine Using Various Fuels. SAE paper No. 780641, 1978, 12 pp.

2. Mitchell, E., et al. A Stratified Charge Multi-fuel Engine - A Progress Report. SAE paper No. 720051, 1972, 9 pp.

3. Bechtold, R. L. and R. D. Fleming. Performance of Gasoline and Diesel Fuels Produced from COED Syncrude. DOE/BERC/RI-78/2, June 1978, 22 pp.

4. Lewis, J. M. and W. T. Tierney. Stratified Charge Engine Development with Broad Fuel Tolerance. Pres. at the First International Automotive Fuel Economy Research Conference, Alexandria, VA, Oct. 31-Nov. 1, 1979.

5. Texaco Inc. 1977 Gremlin with White Engines, Inc. L-163S Stratified Charge Engine. Brochure and instruction booklet prepared at Beacon Research Laboratories, Beacon, NY, April 1979.

TABLE 1. - White/Texaco TCCS engine specifications

| | |
|---|---|
| Model........................ | L-163S |
| Engine type.................. | 4 cycle, naturally aspirated |
| Number of cylinders.......... | 4 |
| Bore, inches................. | 4.00 |
| Stroke, inches............... | 3.25 |
| Displacement, cubic inches... | 163 |
| Firing order................. | 1-3-4-2 |
| Compression ratio............ | 12:1 |
| Maximum gross horsepower..... | 65 @ 3,600 rpm |
| Maximum torque, lb-ft........ | 111 @ 2,400 rpm |
| Fuel system.................. | Direct injection |
| Injection pump............... | Roosa Master DB-2 |
| Weight, lb................... | 389 |

TABLE 2. - TCCS recommended ignition and injection timings

| Test fuel | Timings, °BTDC | |
|---|---|---|
| | Ignition | Injection |
| Unleaded regular gasoline............... | 25 | 28 |
| Diesel/gasoline blend (25 pct diesel + 75 pct gasoline)........ | 32 | 22 |

TABLE 3. - Fuel inspection data

| | Unleaded gasoline (7622) | Oil-shale derived gasoline (7515) | No. 2 diesel fuel (7926) |
|---|---|---|---|
| Specific gravity | 0.718 | - | 0.852 |
| Research octane No | 91 | 80 | - |
| HC/carbon atom ratio | 2.04 | 1.846 | 2.00 |
| Composition, pct by vol: | | | |
| Aromatic | 10 | 32 | 32 |
| Olefin | 14 | 11 | 2 |
| Saturate | 76 | 57 | 66 |
| Distillation, ASTM D-86, °F: | | | |
| IBP | 90 | 89 | 364 |
| 5 pct evaporated | 115 | 112 | 404 |
| 10 " " | 128 | 122 | 417 |
| 20 " " | 156 | 139 | 438 |
| 30 " " | 182 | 154 | 456 |
| 40 " " | 202 | 170 | 474 |
| 50 " " | 218 | 191 | 493 |
| 60 " " | 231 | 218 | 512 |
| 70 " " | 250 | 259 | 534 |
| 80 " " | 286 | 295 | 554 |
| 90 " " | 356 | 325 | 582 |
| 95 " " | 410 | 352 | 602 |
| EP | 424 | 395 | 616 |
| Sulfur content, wt-pct | .028 | 0.006 | - |

TABLE 4. - Effect of test fuel on vehicle economy - 75° F

| Test fuel | Fuel economy, mpg | | |
| --- | --- | --- | --- |
| | Urban (FTP) | Highway (HFET) | Composite |
| Unleaded regular gasoline (7622)..................... | 27.4 | 35.9 | 30.7 |
| 75 pct gasoline/25 pct diesel fuel (7931)......... | 28.1 | 34.3 | 30.5 |
| Shale-derived gasoline (7515)[1]................... | 27.3 | 38.3 | 31.4 |

[1]Results were obtained from a single experiment.

TABLE 5. - Effect of test fuel on exhaust emissions - 75° F

| Test fuel | FTP emissions, gm/mile | | | | |
| --- | --- | --- | --- | --- | --- |
| | CO | HC | $NO_X$ | Particulate | Aldehyde |
| Unleaded regular gasoline (7622)..................... | 2.1 | 1.08 | 1.76 | 0.09 | 0.07 |
| 75 pct gasoline/25 pct diesel fuel (7931)......... | 3.5 | 1.64 | 1.41 | .18 | .10 |
| Shale-derived gasoline (7515)..................... | 2.9 | 0.88 | 2.27 | .15 | - |

TABLE 6. - Exhaust emissions and fuel economy - temperature effects - unleaded gasoline

| | Ambient temperature, °F | | | |
| --- | --- | --- | --- | --- |
| | 20 | 50 | 75 | 100 |
| Fuel economy, mpg: | | | | |
| Urban................ | 24.7 | 27.7 | 27.4 | 28.7 |
| Highway............. | 34.5 | 36.2 | 35.9 | 37.0 |
| Emissions, gm/mi: | | | | |
| CO.................. | 2.1 | 2.2 | 2.0 | 2.1 |
| HC.................. | 2.29 | 1.11 | 1.08 | 1.09 |
| $NO_X$................. | 1.73 | 1.70 | 1.76 | 1.87 |
| Particulate.......... | 0.11 | 0.13 | 0.09 | 0.11 |
| Aldehyde............ | .08 | .09 | .07 | .05 |

TABLE 7. - Exhaust emissions and fuel economy - temperature effects - diesel/gasoline blend

| | Ambient temperature, °F | | | |
|---|---|---|---|---|
| | 20[1] | 50 | 75 | 100 |
| Fuel economy, mpg: | | | | |
| Urban................ | 26.7 | 26.0 | 28.1 | 27.5 |
| Highway............. | 36.1 | 34.0 | 34.3 | 35.8 |
| Emissions, gm/mi: | | | | |
| CO.................. | 3.2 | 5.1 | 3.5 | 4.1 |
| HC.................. | 1.58 | 2.23 | 1.64 | 1.90 |
| $NO_X$................. | 1.24 | 1.43 | 1.41 | 1.66 |
| Particulate......... | 0.16 | 0.19 | 0.18 | 0.18 |
| Aldehyde............ | .1 | .09 | .1 | .08 |

[1]Results were obtained from a single experiment.

TABLE 8. - Effect of catalyst replacement

| Catalyst | Urban (FTP) | Highway (HFET) | Emissions, gm/mi CO | HC | $NO_X$ | Particulate |
|---|---|---|---|---|---|---|
| Original....... | 27.4 | 35.9 | 2.0 | 1.08 | 1.76 | 0.09 |
| Replacement.... | 29.4 | 37.6 | 0.5 | 0.87 | 2.44 | .08 |

TABLE 9. - Alcohol fuels - hot-start tests

| Test fuel | Urban fuel economy, mpg | Urban fuel economy, m/$10^5$ Btu | Emissions, gm/mi CO | Emissions, gm/mi HC |
|---|---|---|---|---|
| Unleaded regular gasoline (7622)... | 29.6 | 25.7 | 0.7 | 1.5 |
| Ethanol............ | 20.2 | 25.7 | .2 | 2.6 |
| Methanol........... | 15.2 | 24.3 | .2 | 1.4 |

TABLE 10. - Injection and ignition timing effects

| Test fuel | Injection/ignition timings, °BTDC | Composite fuel economy, mpg | Emissions, gm/mi | | | |
|---|---|---|---|---|---|---|
| | | | CO | HC | $NO_X$ | Particulate |
| Unleaded gasoline (7622).............. | 28/25 | 32.5 | 0.5 | 0.82 | 2.44 | 0.08 |
| Unleaded gasoline (7622).............. | 22/32 | 32.3 | .4 | .62 | 1.68 | .06 |
| Shale-derived gasoline (7515)...... | 28/25 | 31.4 | 2.9 | .88 | 2.27 | .15 |
| Shale-derived gasoline (7515)...... | 22/32 | 30.1 | 2.9 | 1.29 | 1.60 | .25 |

## SYNOPSIS OF ENVIRONMENT CANADA (EC) DATA

| Test | Emission Control | Cycle | Fuel[1] | Emissions g/mi HC | CO | $NO_x$ | MPG by carbon Balance |
|---|---|---|---|---|---|---|---|
| Canadian Emission Standards | | City | -- | 2.0 | 25 | 3.1 | -- |
| Baseline | No EGR | City | Gasoline | 1.07 | 0.3 | 2.41 | 32.2 |
| | No EGR | Highway | Gasoline | 0.19 | 0.1 | 2.27 | 39.2 |
| End of Test | No EGR[2] | City | Gasoline | 1.46 | 0.5 | 2.52 | 33.4 |
| | No EGR | Highway | Gasoline | 0.28 | 0.3 | 2.25 | 40.6 |
| Texaco Baseline | No EGR | City | Gasoline | 0.9 | 0.4 | 3.29 | 27.2[a] |
| | No EGR | Highway | Gasoline | -- | -- | -- | 38.7[a] |
| DOE Data | {Probably | City | Gasoline | 1.5 | 0.7 | N.A. | 28.1[a] |
| | {No EGR | Highway | Gasoline | -- | -- | -- | 38.6[a] |
| Effect of EGR | No EGR | {City Hot | Gasoline | 1.96 | 0.6 | 1.97 | 37.3 |
| | EGR | {Start | Gasoline | 1.35 | 0.5 | 1.61 | 36.2 |
| Fuel Effects[3] | EGR | City | Diesel #2 | 1.35 | 9.0 | 0.94 | 34.3 |
| | EGR | Highway | Diesel #2 | 0.52 | 3.1 | 1.44 | 41.3 |
| Fuel Effects[3] | {Partial[4] | City | HA Diesel | 0.73 | 2.0 | 1.55 | 34.6 |
| | {EGR | Highway | HA Diesel | 0.17 | 0.5 | 1.59 | 42.4 |
| Fuel Effects[3] | EGR | City | HA WBR | 0.91 | 4.0 | 1.11 | 35.1 |
| | EGR | Highway | HA WBR | 0.30 | 1.6 | 1.44 | 42.0 |
| Fuel Effects[3] | EGR | City | LA WBR | 0.66 | 3.2 | 1.17 | 36.8 |
| | EGR | Highway | LA WBR | 0.24 | 1.4 | 1.53 | 44.4 |

[1] WBR = Wide Boiling Range HA = high aromatic LA = low aromatic.
[2] Although EC reports EGR on-Data indicates EGR inactive.
[3] Probably overfueled with heavy fuels compared to gasoline; EGR tends to increase CO.
[4] Although EC reports EGR on-Data indicates EGR control degrading.
[a] Fuel economy by weight.

## SUMMARY

Engine seems to be operating well, results are repeatable. Multifuel capability demonstrated with all engine settings adjusted by EC. Excellent fuel economy with emissions at all times meeting Canadian standards. EC reckons fuel economy overstated by 5% due to instrumentation calibration. Usual differences between carbon balance and weight determinations of fuel economy noted. EGR control appear inoperative at test end.

Mr. OTTINGER. Very interesting. Thank you very much.

We will hear next from Mr. Merle Fisher.

STATEMENT OF MERLE FISHER

Mr. FISHER. Thank you, Mr. Chairman.

I would like to introduce Mr. Garvin McCurdy, my associate, of Carson Associates. They are commissioned to monitor the technical aspects of our blend program.

Among my responsiblities I manage the buying, selling, maintaining and, to some degree, the operating of the bank's automotive fleet, which totals over 1,800 vehicles of various types.

Because we have more than 1,100 branches throughout the State, we depend heavily on these vehicles, particularly in the area of courier deliver, field services, business development, supervision, and security maintenance roles.

Those functions, along with those of almost everyone in the State of California, were seriously hindered by the gasoline shortage during the spring of 1979. We resolved then to counteract the bank's future vulnerability to the degree possible. Alcohol fuel seemed to offer the best alternative.

Consequently, in late 1979 I ordered a small number of cars modified especially to to run on methanol. They were purchased from Mr. Charles Stone, president of Future Fuels of America. At that time, these vehicles represented the first production automobiles to run on alcohol since the 1920's. We also resolved to assess the use of methanol blends in gasoline with the remainder of the fleet.

The incentives for doing this were not altruistic. They were:

One, if possible reduce the bank's vulnerability to the high cost and future scarcity of gasoline.

Two, the strong possibility of lower maintenance costs because alcohol has a lower carbon content.

Three, the fact that alcohol burns much cleaner could make a positive contribution toward smog reduction.

Four, the program, if successful and adopted by others, could be a step toward less dependence on foreign oil.

Our first methanol car was delivered in February of this year. Our fueling facilities have been modified to dispense both essentially pure methanol and five representative blends of methanol in gasoline.

We are taking pains to record all pertinent data on our facilities and work environment, et cetera, as we go along so that others may benefit from our experience. Cars are being assessed for driveability, emissions, fuel usage, and economic performance. The fuels are being technically assessed for practicality and safety.

The facilities and fuel handling procedures are delivering stable, precisely compounded blends. Incremental costs for a methanol fueling station is about $1,500 for a blend pump and about $3,500 for special tank and plumbing installation.

The incremental cost of a car modified for all methanol operations is under $2,000 on the average. This includes modification to the engine, the fuel delivery system and heavier suspension.

Incremental costs to modify cars for blend usage are less than $40 to install an inline fuel filter and replace selected carburetor components with the like items of different synthetic rubber compounds.

We are incurring startup costs now, but I hope to be able to eventually report decreased maintenance costs on methanol autos, together with significantly better energy efficiency, perhaps on the order of 20 percent.

At this time we are emerging from what I refer to as a shakedown stage with the blend program. We have encountered testing problems and have taken productive steps to solve them.

We cannot provide definitive quantitative results at this point because there is not yet sufficient history from which to draw conclusions. A definitive report will be made after the first quarter 1981.

The methanol cars have been driven collectively over 500,000 miles and perform very well. There have been minor problems, but overall results are extremely positive.

Bank of America with Future Fuels of America will copublish a detailed report at the conclusion of a 1-million-mile demonstration on the methanol cars. We have achieved the first objective of reducing the bank's dependence on gasoline.

As of December 15 we have used 58,021 gallons of methanol in our fleet operation. I have sufficient confidence in them that we have ordered a total of 141, of which 91 have been delivered.

Collection of data on usage with blends varying from 2 percent to 18 percent methanol is just beginning. The initial results look positive for fuel operating costs per mile.

The octane boosting effect of methanol is significant in our situation; fifty cars are running on these blends; fifty additional cars are included in the blend demonstration for control purposes.

Blend cars should show maintenance costs approximately equal to gasoline cars, equal or slightly improved power, and slightly reduced fuel costs. Our older cars are even getting a bit better mileage on blends.

We are also interested in the direct injection stratified charged engine which burns all kinds of fuel. White Engines is proposing to provide us several for testing on gasoline and alcohol as part of the total program.

I have been asked to comment on the national economic potential of total vehicle conversion to methanol fuels. This is an abstraction which cannot be realized without total national commitment.

Obviously, the greater the commitment the faster it will be done.

Realistically, by 1995 perhaps 15 percent of our gasoline could be displaced by methanol, most of it made from coal. This would require about 95 million tons of coal each year. It would require $20 to $30 billion in investment in new plants and generate many new jobs.

A study commissioned by Bank of America indicates:

Methanol yields significantly more highway miles driven per ton of coal mined than any other coal-derived alternatives.

Methanol is an excellent way to use coal from the clean air aspect, both in production and with regard to auto emissions.

Methanol blends prove effective octane boosters and enable the country to reduce the refining required for basic blending gasoline.

This alone could result in measurable indirect reduction of imports in the fairly near term.

Eventually, fuel methanol could supplement raw coal as a fuel export from this country, further favoring our balance of payments.

The energy price of methanol is currently competitive with gasoline and will be even more competitive in the late 1980's when coal methanol comes on line.

Methanol should become even more efficient than gasoline or other hydrocarbon automotive fuels as improved engines are evaluated over the next 5 to 10 years. This advantage may be as low as 10 percent or as high as 40 percent, depending on test results. So, methanol may be a better transportation buy for the consumer.

I view all of these points as a tremendous opportunity for our country. Our demonstration seems to be proving the practicality of methanol's use in the automotive market, as well as its present and potential economies.

Bank of America is proud to be engaged in the effort to develop alternative energy resources and in support of others who are dedicated to that cause.

For its part, the Congress should consider:

Changing mileage requirements from per gallon terms to miles per million Btu's terms, a formula which would make us clearly more energy conscious.

Changing tax on fuel to an energy content basis rather than per gallon.

Revision of the Clean Air Act to permit methanol to be used as a component of fuels 'substantially similar' to gasoline, just as gasohol is today.

Research money should be made available specifically for development of alcohol engines.

Gentlemen, that ends my testimony. Thank you very much for the opportunity to be here.

[Mr. Fisher's prepared statement follows:]

BANK OF AMERICA

SAN FRANCISCO HEADQUARTERS

18 December 1980

TESTIMONY FOR THE ENERGY AND POWER SUB COMMITTEE OF THE HOUSE INTERSTATE AND FOREIGN COMMERCE COMMITTEE ON THE BANK OF AMERICA'S ACTIVITIES WITH METHANOL AND AUTOMOTIVE FUEL

Chairman Dingell, Gentlemen, I am Merle Fisher, Vice President of Administration for the Bank of America. Among my responsibilities is the management — that is, the buying, selling, maintaining, and, to some degree, the operating — of the Bank's automotive fleet which totals over 1500 vehicles of various styles. The Bank depends heavily on these vehicles, particularly in courier, security and maintenance roles. Thus, my functioning — together with that of almost everyone in the entire state of California — was seriously hindered by the gasoline shortage of the Spring of 1979. I resolved then to counteract the Bank's vulnerability to any future shortages to the degree possible. Methanol offered the best possibility to do this.

Consequently, in late 1979, I ordered a small number of cars modified especially to run on methanol from Mr. Chuck Stone of Future Fuels of America, and modified my fueling facilities to handle methanol fuel. The vehicles produced by Future Fuels of America represent the first production alcohol cars produced in this country since Ford produced methanol cars in the 1920's. I also resolved to assess the use of blends in gasoline with the remainder of the fleet. The reasons for doing this are not altruistic. They are:

- To reduce the Bank's vulnerability to future gasoline shortages.

- The Bank's prosperity depends on California's prosperity which depends on the automobile. The same holds for the entire nation, and — in the final analysis — the whole world. Our experience could prove a guide to reducing gasoline dependence.

- If methanol is as good as it looks and sounds, a major new fuel methanol industry will develop. The Bank will no doubt play a role in financing sound ventures of this kind.

- The methanol demonstration produces positive attitudes in our employees and in our community. We are not sitting around waiting for events to overtake us.

- Lastly, if this nation has a clearly viable auto fuel alternative, the chance of our country becoming involved in war in the Mid East is reduced.

Our first methanol car was delivered in February of this year. Our fueling facilities have been modified to dispense both essentially pure methanol and five representative blends of methanol in gasoline. We are taking pains to record all pertinent data on our facilities, our procedures, our work environment, etc., as we go along so that others may benefit from our experience. The cars are being assessed for driveability, emissions, fuel usage, and economic performance. The fuels are being technically assessed for practicality and safety.

At this time we are emerging from what I refer to as a shakedown stage where we have encountered teething problems and taken steps to solve them. I cannot provide definitive quantitative results at this point, because there is not yet sufficient history from which to draw conclusions. But I can state that I have achieved my first objective of reducing the Bank's dependence on gasoline.

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Collection of data on blends varying from 2 to 18 percent methanol is just beginning. The initial results look positive for fuel operating costs per mile. The octane boosting effect of methanol is significant in our situation. Fifty cars are running on these blends. Fifty additional cars are included in the blend demonstration for control purposes.

The facilities and fuel handling procedures are delivering stable, precisely compounded blends. Incremental costs for a methanol fueling station is about $1500 for a blend pump and about $3500 for special tank and plumbing installations. The incremental cost of a car modified for all methanol operation is under $2000 on the average. This includes modification to the compression ratio, the fuel control, a larger fuel tank, and a stiffer suspension.

Incremental costs to put cars on blends are less than $40 to install an in-line fuel filter and replace selected carburetor components with like items of different synthetic rubber compounds.

We are incurring start up costs now, but I hope to be able to eventually report decreased maintenance costs on methanol autos together with significantly better — say 20 percent — energy efficiency.

Blend cars should show maintenance cost equal to gasoline-fueled cars, equal or slightly improved energy efficiency, and slightly reduced fuel costs. Our older cars are even getting a bit better mileage on blends.

I am also vitally interested in the direct injection stratified charge engine. White Engines is proposing to provide us some for use on gasoline and alcohol as part of our total program.

I have been asked to comment on the national economic potential of total vehicle conversion to methanol fuels. This is an abstraction which probably can't be realized without a total national commitment until after the year 2000. Realistically, by 1995 perhaps 15 percent of our gasoline could be displaced by methanol — most of it made from coal. This would require about 95-million tons of coal. It would require 20 to 30 billion dollars in investment in new plants and generate many new jobs. Our economic research indicates:

- Methanol yields most highway miles driven per ton of coal mined by a wide margin.

- Methanol is an excellent way to use coal from the clean air aspect — both in production and with regard to auto emissions.

- A healthy fuel methanol industry will have positive balance of payments effects by putting a competitive lid on the price of imported oil.

- Methanol blends will prove effective octane boosters and enable the country to reduce the refining required for basic blending gasoline. This alone could result in measurable indirect reduction of imports in the fairly near term.

- Eventually, fuel methanol could supplement raw coal as a fuel export from this country, further favoring our balance of payments.

- The energy price of methanol should be clearly competitive with gasoline in the late 1980's when coal methanol comes on line.

- Further, methanol should be more efficient than gasoline or other hydrocarbon automotive fuels as improved engine technologies are evaluated over the next five to ten years. This advantage may be as low as 10 percent or as high as 40 percent depending on test results. So methanol should be a better transportation buy for the consumer.

I view all of these points as a tremendous opportunity for our country. It all rests on proving the practicality of methanol's use in the automotive market as well as its present and potential economies. I am proud to play a part.

For its part the Congress can play an even more significant role.

- Capital costs for coal methanol plants will be high. Investment credits and liberal depreciation rules aimed specifically at making loan payback possible in 8 to 10 years will bring their capitalization within reach of the commercial banking community.

- The erosive effect of inflation on savings — which are funds available for investment — must be controlled.

- The emissions rules for development of methanol (and other fuel) engines must be relaxed to a "no significant degradation" basis. The Clean Air Act can safely be revised to permit this.

- Mileage requirements for autos should be changed from miles per gallon terms to miles per million Btu terms.

- The tax on fuel should be revised to an energy content basis rather than per gallon.

- The prohibition of methanol in the current ruling on fuels "substantially similar" to gasoline under Section 211f of the Clean Air Act should be reversed.

- A conservation bonus tax credit should be devised for encouraging production of fuels and autos which result in most miles driven per ton of coal mined.

- The use of peat and biomass for methanol production should be encourage.

- The technical assessment of geopressured methane should be accelerated at highest priority. This is a raw material which could rival coal if available in the quantities currently estimated.

- Research money should be made available specifically for development of alcohol engines.

Gentlemen, this ends my testimony. Thank you very much for the opportunity to be heard. Free our hands and let us go forward.

Mr. Ottinger. Thank you very much, Mr. Fisher.

We will hear last from Mr. Thomas W. Browne, vice president, United Parcel Service, who has visions, I take it, that when we have run out of oil and the Post Office fleet is stopped, United Parcel will take over.

## STATEMENT OF THOMAS W. BROWNE

Mr. Browne. Thank you, Mr. Chairman.

We have filed a detailed statement for the record [see p. 53], and I will now give a quick summary of that material to put it into perspective.

Before I do so, I want to thank the committee for inviting United Parcel Service to give an accounting of what we believe to be a very significant technological development that advances this Nation's capacity to function with limited petroleum supplies.

With me today is Jim Lewis, UPS automotive engineer, who set design criteria for the UPS–292–SC engine and who will respond to any technical questions posed by the committee.

As a commercial fleet operator, United Parcel Service purchases engines and chassis from the major American auto manufacturers, then adds custom bodies which are highly efficient workplaces for our package delivery drivers. We do not build engines.

When we began assessing our automotive needs for the 1980's we identified as major problems one, emission standards; two, fuel efficiency; three, fuel quality and availability; finally, the biggest problem of all, the fact that there were no power plants to take us over these hurdles.

Part of our fleet consists of some 35,000 package delivery vans, and our prior experimentation with diesel engines proved conclusively to our engineers that this type engine was not a viable alternative for the 1980's.

We needed an engine to retrofit our fleet. We couldn't throw away 35,000 aluminium body delivery vans.

In our search for solutions we became aware of Texaco's technology, and in April 1978 we entered into a contract with Texaco for development of a multifuel engine.

Texaco determined that a GM engine common in our fleet was so configured that by changing some parts it could be converted to the Texaco stratified charge engine technology. Subsequently, we calculated that the parts cost for this conversion would be only about $1,300 per engine, involving a new head, manifolds, pistons, ignition system and injection system.

The first prototype of this engine was delivered last February from Ricardo Engineering consultants in England, where engine component design work took place. Test stand results were right on the fuel projection curve that Texaco engineers had promised their technology would deliver.

When we installed the engine in a package delivery van and tested it against an identical van powered by an unmodified version of the GM engine, we were elated.

The fuel comparison results are listed on the board, and also an emissions chart. This is without doing anything, just converting the engine to the stratified system. This information, as well as the emission chart information, is contained in our detailed statement.

Stated conservatively, this engine delivers a fuel performance improvement of more than 35 percent. Overall, it will do 10 percent better than a diesel engine of similar size. It is particularly efficient in the stop and go of city driving in which so many of our vehicles are involved.

This engine will run on any automotive fuel. It is not sensitive to octane and cetane ratings. It runs well on a wide boiling range fuel, which can be produced with the least expenditure of crude at the refinery. This engine makes dramatic savings on the road and at the refinery as well.

We have had a lot of cooperation on this project from the private sector—General Motors, Stanadyne, Echlin, TRW, Rockford Clutch, Standard Thomson, Clifford Manufacturing, and many other firms, which in one way or another assisted in this project, and in some instances put substantial capital at risk to improve components for this new engine.

The noise regulation group of the Environmental Protection Agency has expressed an interest in testing the engine, and just recently the Department of Transportation has also approached us. An Air Force task force, seeking improved fuel economy for its ground fleet, also has asked to be apprised of progress.

The Canadian Government is quite anxious to obtain some of these engines for testing of alcohol fuels and other purposes. They have a streamlined approach to the propulsion plant/fuels problem, and we anticipate that they will be involved in this program at some future date.

We have taken a calculated risk in developing this engine, given the stringent emission regulations now in force and projected for the future. The EPA has granted us a waiver of the engine tampering laws for the purpose of testing 10 of these engines. We felt we were improving an engine, not tampering with it.

Mr. Dingell. What is the number of vehicles on which you got the tampering rule waived?

Mr. Browne. Ten, sir.

Mr. Dingell. How many did you request?

Mr. Browne. Well, initially we had asked for 500, so we could test them on all different parts of the country, in all different climatic conditions. But that was too large a number to be coped with apparently. We were given an exemption for 10.

We plan to apply again, having now some hard data of actual on-the-road experience, and we hope that they will have the wisdom to understand that this is an improvement on an engine.

While this engine burns fuel cleanly, as you can see from the emission test results on the board, we believe that the fuel savings potential of this engine will be a consideration if any emission problem should arise that we may encounter in the future.

Mr. Ottinger. Can you just briefly explain that chart?

Mr. Browne. The emission one?

Mr. Ottinger. Yes.

Mr. Browne. By just converting the engine without doing anything to reduce emissions or put any catalytic converters or anything on, the converted engine has lower carbon monoxide than a standard engine. It has higher hydrocarbons than a standard engine, but still well beneath the tailpipe standards of New Jersey, California and Oregon. We feel by working on the engine, we can reduce this.

Mr. OTTINGER. Thank you.

Mr. BROWNE. At least on the results of our tests, we believe that this is the engine of the future for UPS. We give great credit to the patience of Texaco engineers in developing this technology.

This is not just an engine to power package delivery vans. Our project only happens to be an acid test of technology that has proved itself in the past, but has not been utilized.

This engine represents a technological leap in engine design that should serve us well for that future period when we await the coming of the more exotic powerplants that the Federal Government has been supporting with its research funds.

Based on the results of our tests we believe that this is the engine of tomorrow for UPS in the conversion of our existing fleet and we give great credit to the patient persistence of the engineering at Texaco who refined this technology.

We will now be pleased to answer any questions.

Thank you very much.

[Testimony resumes on p. 81.]

[Attachment to Mr. Browne's prepared statement follows:]

# REPORT ON A STRATIFIED ENGINE PROJECT

FROM

UNITED PARCEL SERVICE

United Parcel Service is a privately owned corporation that operates the largest motor carrier fleet in the world. The company does not manufacture motor vehicles or any automotive components. Its sole activity is the use of motor vehicles in the transportation of goods. These vehicles are not standard production line models. Each type, from the gasoline-powered delivery vans to the diesel tractors, is highly customized for its particular job.

Corporate policy and practice dictate that fleet vehicles shall be the most efficient and reliable produceable. This policy requires that company engineers be alert to changing technology and future operating conditions.

When corporate planners looked at the technology available for the 1980s, and the potential operating conditions that could prevail, they found three distinguishable problems:

- Emission control requirements will become more stringent.

- Vehicles will have to become more fuel efficient, and there will be strong government pressure to introduce diesel engines in light and medium duty trucks to meet that objective.

● Fuel availability will be a question mark, both as to quantity and type of fuel, which may include synthetics or shale derivatives.

The obvious need for UPS was an engine that could satisfactorily accommodate all three problems. The engine must have low emissions, consume fuel efficiently and have a broad fuel tolerance. No commercial engine is available to meet these requirements in the 1980s, and still satisfy cost criteria and other practical considerations.

United Parcel Service has a unique fleet characteristic that further complicated the search for a solution: The long life of its vehicles. Delivery vans have aluminum bodies and are assembled with heavy duty components to ensure durability and longevity. As part of its fleet the company has 35,000 package delivery vans, and any decisions about power plants had to include the possibility of retrofitting this large fleet.

We believe the engine we now are developing--The UPS 292 SC--will meet all of the fuel problems we will face in the 1980s.

The 292-cubic-inch stratified charge engine conversion, which United Parcel Service is developing from technology supplied by Texaco, could be retrofitted into about three quarters of our fleet. Based on test data to date, we believe these conversions would generate a fuel savings in excess of 35 percent and be highly cost effective.

While the currently popular method of gauging fuel conservation is the miles per gallon that a vehicle obtains on the road, such a measurement ignores the excessive amounts of crude oil that are consumed at the refinery to produce such fuels as high octane unleaded gasoline. A proper measurement of fuel efficiency has to include both refinery efficiency and vehicle efficiency.

The UPS 292 SC does not require fuel with a high octane or cetane rating. It will burn any automotive fuel between diesel and gasoline, and could with modification operate on pure alcohol. It will run most efficiently on a wide boiling range fuel. Refining of this fuel consumes the least amount of crude in the production process. Thus we believe this engine will give a 35 percent fuel improvement on the road, and an additional savings at the refinery.

The true measurement of fuel efficiency must become the number of miles of transportation obtainable from a barrel of crude, not just the number of miles per gallon that a vehicle obtains, from a fuel that may be very wasteful of crude oil during distillation.

Before United Parcel Service took the extreme step of becoming involved in engine development, it had exhausted every other avenue of maximizing mileage for its delivery fleet. It adopted radial tires, electronic ignition, fuel efficient drive line ratios, fan clutches, aluminum bodies and aerodynamic design. Through a computerized preventive maintenance program it ensured meticulous tuning of engines. Drivers were taught to operate vehicles for maximum fuel savings. All engines are shut down at each stop. Delivery routes were reworked by engineers to produce the most work in the least number of driven miles. Vehicles of assorted sizes were provided to make certain that the vehicle was neither too small nor too large for its assigned job.

This total effort was insufficient to meet the fuel problems coming in the 1980s. Accordingly, United Parcel Service entered into an engine development project.

Why The Diesel Alternative Will Not Work

Several foreign and domestic makes of medium duty diesel engines were evaluated in UPS package vans since the 1960s, but overall results have been disappointing. Fuel savings as high as 21 percent were recorded, but initial costs and operating expenses were prohibitive. In addition, many other problems were encountered with the diesels tested, such as:

- Increased engine weight, larger radiators, larger air cleaners, heavier batteries, etc. required heavier front suspensions and upset the standard weight distribution.
- The relatively low rpm of the available diesel engines required the use of an overdrive transmission because faster rear axle ratios were not available.
- The higher torque output and torsional vibrations required larger and more expensive clutches, transmissions and drivelines.
- Increased radiator and air filtration requirements caused space problems in the engine compartment.
- Driver and mechanic retraining were necessary.
- Starter problems were a constant source of road calls and downtime due to the failure of starters to cope with some 200 starts per day.
- Complaints were voiced about exhaust fumes and odor when vehicles were operated within buildings.

- Additional expense and maintenance was necessary for insulation in the engine compartment to keep the vehicle interior noise within limits set by the Bureau of Motor Carrier Safety (BMCS).

Although some new diesel engines have recently appeared on the American market, the initial cost, the impracticability of retrofit, the added size and weight, and the potential problems experienced in past diesel evaluations remove them from the list of near-term solutions for UPS.

Likewise, Stirling engines, gas turbines, Wankel engines, electrics, hybrids, and others are too experimental to be considered viable near-term solutions for a delivery business that must have dependable vehicles with low maintenance and operating costs.

These futuristic power plants will require widespread application and acceptance in passenger cars before thought can be given to their use in service trucks.

Texaco Technology Showed Promise

In its quest for a near-term solution, UPS became aware of the Texaco Controlled-Combustion System (TCCS), which is a broad-fuel-tolerant, stratified charge engine.

Further investigation revealed that Texaco engineers had done an impressive amount of work on this concept over the years, and have completed many successful stratified engine conversions. United Parcel Service decided to explore the feasibility of a stratified charge engine conversion for one of the two gasoline engines used to power the bulk of the UPS fleet.

A feasibility study conducted by Texaco engineers on both the GMC 292 and the Ford 300 six-cylinder engines revealed that only the GMC 292 could be considered for modification to the stratified charge design without major changes to the block and its components.

In April, 1978, UPS entered into a development contract with Texaco assisted by Ricardo Consulting Engineers Ltd. as subcontractor to convert the GMC 292 to the TCCS technology.

The original agreement between UPS and Texaco called for conversion of a single prototype engine, including complete dynamometer evaluations, initial vehicle installation and evaluation.

A single-cylinder model of the multi-cylinder engine was fabricated to assist in the design of the multi-cylinder engine. This program was later expanded to include four converted multi-cylinder engines which will be detailed later.

An engine conversion development is an unusual undertaking for a fleet that had no manufacturing capability and whose engine facilities are limited to repair and overhaul. Despite these limitations, the potential benefits of a stratified charge conversion of an existing, proven gasoline engine has great promise in meeting UPS's current and future fuel problems.

Modifications of a manufacturer's standard engine to increase speed or performance is a commonplace occurrence in the hotrod and racing fraternity. For the most part, the engine block and components serve as the foundation to which increased-performance components are fitted to obtain the desired results. In the UPS stratified engine program, the GMC 292 engine block serves as the foundation for additional components developed by Texaco and Ricardo to improve fuel economy and the general operational characteristics of the engine.

The Texaco feasibility study identified major components that had to be developed, replaced, or modified to achieve the conversion. The cost of these components, over those that can be retained from the GMC 292, were estimated by UPS to arrive at a total estimated differential cost of the UPS 292 SC. These estimated costs were determined by consulting Texaco engineers, speed equipment manufacturers, machine shops, and engine component suppliers. They do not reflect pattern, tooling or development costs:

| | |
|---|---|
| Cylinder head | $400 |
| Exhaust manifold | 50 |
| Intake manifold | 35 |
| Fuel injection & ignition systems | 400 |
| Camshaft | 70 |
| Valve cover | 30 |
| Valves, rockers, springs, etc. | 100 |
| Pistons & rings | 90 |
| Fuel pump | 10 |
| Vacuum pump | 20 |
| Injection pump drive | 70 |
| Linkage, brackets, gaskets, etc. | 25 |
| TOTAL | $1,300 |

This component list represents the bulk of the add-on or substitute parts necessary to convert a GMC 292 engine to a UPS 292 SC at time of engine overhaul. Whether the original block is rebuilt or a new block is purchased, the labor cost added to the UPS 292 SC component cost would vary only slightly.

The converted engine could be installed in a GMC package van with the same ease as a standard engine. The only extras would involve: Reworking the throttle linkage, rerouting fuel lines, relocating the air cleaner and fabricating new exhaust connections. When installed in a Ford package van, all of the above items would require rework plus the addition of a new bell housing (approximately $100) and additional rework to radiator connections, clutch linkage and engine mounts.

For purposes of comparing the total engine cost of a UPS 292 SC ready to install in a package van, with that of a groomed diesel engine of comparable horsepower and performance, the Ford package van installation was selected. This installation is the most difficult and costly, and therefore the fairest comparison with the diesel. It would involve the following modification costs:

| | |
|---|---|
| New GMC 292 short block, less components to be replaced | $ 450 |
| Components to convert to UPS 292 SC | 1,300 |
| New bell housing | 100 |
| Flywheel, clutch, linkage | 90 |
| Water pump, thermostat housing | 20 |
| Starter, alternator, mountings | 95 |
| Engine mounts | 30 |
| Balancer, pulleys | 40 |
| TOTAL | $2,125 |

The preceding list represents the component costs of a fully groomed UPS 292 SC engine ready to install in a Ford package delivery van. To complete the installation the following modifications or replacements would be necessary:

- Cooling system - new radiator connections
- Exhaust system - new connections
- Intake system - new larger air cleaner
- Throttle linkage - reworked
- Fuel lines - rerouted
- Clutch linkage - reworked
- Engine mounts - new

A current diesel engine of about the same horsepower would cost $4,500 to $5,000 groomed to install in a Ford package van. Starting from that point, the following items would require modification or replacement to complete the installation:

- Cooling system - new larger radiator with connections
- Exhaust system - completely new to attenuate the additional noise
- Intake system - new larger air cleaner
- Throttle linkage - reworked
- Fuel lines - rerouted
- Clutch linkage - reworked
- Engine mounts - new
- Transmission - new overdrive transmission to obtain desired road speed
- Front axle springs - new heavier springs to accommodate additional engine weight
- Drive line - heavier driveshaft and U-joints due to increased torque



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- Starting system - increased battery capacity for starting
- Cab insulation - cab noise insulation needed due to increased engine noise level

In comparing the estimated groomed engine cost of the UPS 292 SC ($2,125) with that of the diesel ($4,500 to $5,000), the diesel engine cost alone is approximately double the UPS 292 SC. Taking the full installation into account, it can be readily observed that the diesel installation requires a great deal more chassis work and additional components than the lighter weight UPS 292 SC installation. The additional expense of such major items as: New radiator, new exhaust system, new transmission, new driveshaft, new springs, larger batteries, and additional cab insulation shows the impracticality of retrofit diesel engine installations in UPS package vans. It also provides additional justification for the stratified conversion development program.

Engine Design Objectives

The design of the UPS 292 SC conversion components centers about Texaco's stratified charge, broad-fuel-tolerance combustion process (TCCS). Texaco's technology encompasses expertise in this process as well as knowledge and experience with many other components functionally related to the operation and the success of this type of engine.

As noted earlier, UPS is not in the engine manufacturing business, and therefore relies heavily on the expertise of Texaco and its subcontractor, Ricardo, to make the major decisions on proper design for the engine. UPS's role in the conversion design was one of guidance based on: Familiarity with the design, operation, and maintenance of the vehicles which will utilize this engine; concern about engine component reliability, future production and cost; and the desire to utilize standard or available components wherever possible and practical.

The following engine design objectives were formulated by UPS to provide guidelines for the contractors:

- Design for broad fuel tolerance operation favoring gasoline.

- Utilize the tried and proven engine block and components of the GMC 292 engine wherever possible to: (1) Reduce the cost of future conversion kits, (2) reduce the number of newly designed components that must be tested for reliability, and (3) reduce the number of alterations that must be made to accommodate the conversion kit.

- Utilize components that are standard, available automotive hardware such as valves, rocker arms, push rods, head bolts, etc.

- Design the conversion kit to allow ease of installation of the UPS 292 SC in both GMC and Ford package cars.

- Design for adequate room at the front of the engine to accommodate present and future accessories: Alternators, power steering pumps, etc. An electric fan mounted on the radiator will be used with the converted engine installations.

- Design the new head with accommodations for present and future needs of temperature, pressure, and oil sensors for emissions and maintenance monitoring.

- Design the head for compatibility with the latest GMC 250 headgasket.

● Explore the optional use of a turbocharger for higher horsepower and better emission control.

● Intake manifold to be designed to accommodate a standard air cleaner type such as the Olds diesel.

● Where noticeable weakness exists in the present engine design more reliable components and practices should be explored and utilized.

Ricardo Consulting Engineers Ltd. of England, one of the premier combustion engine engineering firms in the world, conducted a thorough analysis of the GMC 292 block components and found them suitable for the conversion to Texaco technology.

Designs, drawings and patterns were made for the major components including cylinder head, exhaust manifold, intake manifold, injection pump, drive gear case, water pump, valve train, camshaft and various drive gears.

Details of component design to achieve the TCCS requirements included:

● Cylinder Head - This design task is the most difficult since it is necessary to provide for the proper fuel injector and spark plug location, intake and exhaust port position and profile. This must be achieved while utilizing the standard engine head bolt and push rod locations. Water passages have to be located to register with those of the block and, within the head, to provide adequate cooling without the risk of head distortion.

The intake port was designed to provide for proper rate of air swirl at a good level of volumetric efficiency over the speed range. It has been determined that this criterion can best be met in engines having approximately equal bore and stroke dimensions. The port shape is such as to permit a modest amount of core float during the head casting process.

Injector position and spray shape must be coordinated with spark plug location to assure broad load and speed range operation without misfire. The shape of the combustion chamber in the piston crown is also a vital aspect of the overall system consideration.

- Valve train - Intake valve timing, size, and motion are designed to provide the rate of change of flow area to yield proper breathing and air motion. Each intake port is discrete. Since the piston crown has minimum clearance to the bottom of the cylinder head, a camshaft design for rapid valve motion with little valve overlap was utilized. For the GM 292 engine conversion, commercially available roller follower hydraulic tappets were used. The camshaft material was selected to be compatible with these lifters.

- Accessory drives and changes - To provide a drive for the injection pump a new gear case was provided with a half-speed gear driven by the camshaft gear. A special casting was designed for the injection pump mounting pad and drive shaft, as well as the distributor mounting and drive. The former GM 292 distributor location was utilized for a stub shaft and gear to drive the oil pump.

Since the UPS 292 SC is an unthrottled engine, a vacuum pump was required to provide brake system power boost. A commercially available diesel engine vacuum pump was adapted so as to be mounted on the normal gasoline fuel pump boss of the GM 292 and driven by an eccentric on the camshaft.

● Thermostat - Because a TCCS engine is unthrottled and thus has low levels of heat loss at part load, a special thermostat was designed by Standard-Thomson Corporation to isolate the engine block until jacket temperature rises to a desired level. This was necessary to minimize engine warm-up time and to provide driver compartment heat. A thermostatically controlled electric fan is mounted directly on the radiator to provide cooling on demand.

● Ignition system - A unique, alternating current, high-energy ignition system was developed some time ago to provide ignition under the high-velocity air swirls and 10 to 13 to 1 compression ratios normally used for TCCS engines, some of which are supercharged.

For the UPS 292 SC engine, The Texaco Ignition System (TTIS) is triggered by each of the fuel injection nozzles. The injector opening signal occurs during a gating period of fixed crankangle degree duration starting before injection for the desired ignition timing range. The TTIS provides energy to the spark plug for the duration of the injection.

The spark plug utilizes a standard ceramic and center electrode unit. Three ground electrodes are used to permit use of threaded plugs without the possibility of having the spark gap masked from the fuel spray. Good plug service life has been demonstrated in previous and current TCCS test programs.

● Fuel injection system - A Stanadyne fuel injection system is utilized. The pump was tailored to provide the pumping rates and injection duration desired without undesirable spurious or intermittent injection.

Since operation on gasoline is necessary in the fuel-lubricated pump, metallurgy changes in the camcase were developed by Stanadyne. Durability tests several years ago proved the viability of these changes.

The fuel injectors, based on standard units, were modified to provide an injection signal for the ignition system triggering. Very low sac volume, non-axial spray types are utilized.

Castings were made and machined in England, components assembled, and the first UPS 292 SC engine was delivered to the Texaco lab in February 1980.

Program Expansion

In August, 1979, however, based on the excellent progress of the project and the interest of potential component suppliers, UPS decided to expand the program from one multi-cylinder engine to a total of four multi-cylinder engines. This expanded program would accelerate testing and give us:

- An engine to be mounted in a package van at the earliest practical date.
- An engine to be subjected to complete thermal and mechanical durability test.
- An engine for test stand evaluation of performance, emissions, and sensitivity to fuel.
- Sufficient machined spare parts for a fourth engine.

This would provide additional experience, allow for possible prototype engine failure, provide the opportunity for additional testing, and in general speed up the introduction of converted engines into the fleet.

Results of Initial Testing

The first prototype multi-cylinder engine was shipped to Texaco for performance testing in February 1980. The second was shipped to Texaco in June 1980 to replace the first engine on the test stand. The first engine was installed in a UPS P-600 parcel delivery van for road tests in August.

All fuel economy and performance evaluations of the UPS 292 SC engine have been made in a direct comparison with a 1979 GMC 292 gasoline engine, installed in an identical UPS P-600 delivery van. This unit serves as the control vehicle for a two-truck test. Each carried a payload of approximately 4,000 pounds. The vans had identical gross vehicle weights of 12,000 pounds. These were the results:

| | Standard Engine | Stratified Charge | Percent of Gain |
|---|---|---|---|
| Engine Idle | .75 gal./hr. | .31 gal./hr. | 142.0% |
| City Driving To/From Delivery Area | 7.2 mpg | 9.4 mpg | 30.6% |
| Highway Driving Rolling Country | 8.6 mpg | 10.3 mpg | 19.8% |
| Start/Stop Mode During Delivery | 6.3 mpg | 8.7 mpg | 38.1% |

As with all fuel economy tests, the results can vary according to driving technique, ambient temperature, fuel, wind, load, and other factors. Although results achieved have exceeded expectations, the repeatability of the data has given engineers a high confidence in the excellent fuel economy characteristics of the UPS 292 SC engine in package delivery operation cycles. As more prototype engines become available for road testing, a broader base of experience will be obtained.

Fuel economy improvement was the predominant reason for United Parcel Service's decision to enter into the TCCS engine development program. Therefore, it was extremely important to obtain valid fuel economy and performance comparisons in order to provide management with the necessary data to decide on the future expansion of the program.

The test vehicles are identical in test load, transmission, rear axle ratios, tire size and type, and body design. Factors affecting fuel economy and performance, such as lubricants, wheel bearing adjustment, wheel alignment, tire pressure, etc., were continually monitored.

Systems Corporation Model ERD flow meters with reset counters reading in hundredths of a gallon increments were installed on each vehicle. The UPS 292 SC installation required the use of an accumulator float tank to accommodate the return fuel from the injection pump.

Odometer and speedometer accuracy were checked and corrected to assure valid results. An engine tachometer and a recording tachograph were installed in each vehicle. Thermocouples were installed on the UPS 292 SC engine to closely monitor cooling, inlet air, exhaust, fuel and oil temperatures. Pressure sensors were also installed to obtain engine oil and fuel pressure readings.

The engine has operated very satisfactorily over a full speed range from idle up to 3,200 rpm without misfire or knock. An upper limit of 3,200 rpm was imposed on the engine operation to assure prototype engine life with the newly developed components.

Although the majority of the preliminary road tests were conducted with gasoline as the primary fuel, a simulated wide boiling range fuel (75% gasoline, 25% diesel) also was evaluated. The engine fuel and ignition system settings were not modified to accommodate the wide boiling range fuel during the tests. No significant difference in starting, performance or fuel economy was noted.

Increased exhaust smoke occurred during acceleration and under certain load conditions. Some of the smoke could be eliminated by fine tuning the fuel and ignition systems for wide boiling range fuel, but the development of an injection pump load control will be needed to eliminate it with all fuels.

Acceleration, driveability and response of the UPS 292 SC-powered P-600 is almost identical to that of the standard GMC 292-powered P-600. The stratified charge engine idled smoothly without "hunting" at about 700 rpm. A throttle body was originally installed on the intake mainfold to aid idle operation and provide vacuum at idle, but was found to be unnecessary because of the excellent idle characteristics and the sufficient output of the vacuum pump.

Hot and cold (100$^{\circ}$F, 30$^{\circ}$F ambient temperatures) starting characteristics have been excellent with the standard GMC starter motor. The vehicle can be accelerated immediately to highway speeds without stumble or misfire. No false starts have been noted. This winter, further cold start evaluations will be made. Past TCCS engine conversions have exhibited excellent startability in extremely cold weather.

The stratified charge engine is equipped with a no-leak thermostat with controlled flow characteristics and an electric temperature demand fan to closely control engine temperature. The stop and go conditions of package delivery operation require retention of as much heat as possible in the engine block in cold weather for driver warmth and engine operating efficiency. Despite some cooling system fill problems, the cooling arrangement has performed satisfactorily under heavy engine loading during high ambient temperature conditions, (100$^{o}$F). Cab heat and engine operating temperature tests are scheduled for this winter.

Idle emission checks were conducted on both the UPS 292 SC and the GMC 292-powered package vans utilizing NDIR state inspection type equipment. Here are the results and current state standards:

| | Carbon Monoxide | Hydrocarbons |
|---|---|---|
| Stratified Charge Engine | .05% | 115 ppm |
| Standard Engine 1979 Model | .15% | 30 ppm |
| New Jersey Standard Light Duty Vehicles | 2.00% | 200 ppm |
| California Standard Light Duty Vehicles | 1.50% | 150 ppm |
| Oregon Standard Heavy Duty Vehicles | 2.00% | 250 ppm |

Exterior and interior noise levels of both the standard and the TCCS-powered package vans were taken according to

Bureau of Motor Carrier Safety stationary run-up test procedures. The results were:

| | BMCS Interior Noise Test dbA | | BMCS Exterior Noise Test dbA (50 ft.) | |
|---|---|---|---|---|
| | As Tested | Max. Allow. | As Tested | Max. Allow. |
| GM 292 | 83 | 90 | 77 | 86 |
| UPS 292 SC | 90 | 90 | 77.5 | 86 |

The exterior noise level of the UPS 292 SC-powered package van is equal to that of the standard van for practical purposes, and well under the BMCS maximum decibel level. The interior noise level of the TCCS-powered van just meets the BMCS maximum with the present rear engine cover. Past experience with diesel engine installations in similar vehicles has shown the need for accoustical material on the engine side of the rear engine cover. This type of material will be installed in the near future and the vehicle will be retested.

Program Status and Expansion

At this point, 30 months into the UPS stratified charge engine development, the program has progressed very close to the original schedule with no major design or development problems.

The following is a list of milestones to date in the UPS 292 SC development program:

| | |
|---|---|
| April 1978 | Contract signed with Texaco. |
| April 1978 to date | Single cylinder development engine built up and utilized to evaluate piston design, injector design, air swirl patterns, fuel pump requirements, spark plug configuration, ignition system |

| | |
|---|---|
| | characteristics, clearance problems, operation on various fuels and other parameters important to multi-cylinder design. |
| October 1978 - July 1979 | Ricardo, with assistance from Texaco, designed the engine conversion components. |
| July 1979 - Jan. 1980 | Patterns for the prototype multi-cylinder engines were procured by Ricardo and sent to foundries for castings. Machining and fabrication was done by Ricardo and outside facilities. |
| February 1980 | Ricardo assembled the first prototype engine and conducted a brief proof run-in test and shipped the engine to Texaco. |
| March 1980 | Texaco installed the first prototype engine on a test dynamometer for performance evaluation. |
| August 1980 | Prototype engine installed in UPS P-600 package delivery van for road testing. |
| September 1980 | Preliminary road tests conducted by UPS and Texaco to compare UPS 292 SC and GMC 292-powered delivery vans in simulated service. |
| September 1980 | UPS management decision to expand the program to include 10 additional prototype engines and a 500-engine field test program. |

As engineering work has progressed over the past two and a half years, contacts have been made with various component suppliers and machine shops to establish that engines, beyond the original prototypes, could be produced at reasonable cost. A major breakthrough was the interest shown by a Michigan machine shop facility with production type machinery. Utilizing this facility, plus the outstanding support shown by other component suppliers, it now will be possible to build 10 additional prototype engines within the next six months. Initial component, tooling, and machining pricing indicate that engines for a 500-

engine field test can be built for less than the cost of a comparable diesel engine of the same horsepower.

Emission regulations are the largest cloud over this engine development program. Past work by Texaco has shown that the TCCS concept is responsive to emission control technology. Initial idle emission levels, tested according to state test procedures, show that even in its early stage of development, the UPS 292 SC engine will meet existing state emission regulations with a wide margin of compliance. UPS has obtained an exemption from the EPA to continue test and development work on 10 engines. The amendments to the tampering section of the Clean Air Act, which includes fleets, are unclear with respect to certification for add-on components, retrofit engines, and conversion of existing engines. Clarification of this question will be necessary before any extended field test of the UPS engine can be conducted.

Based on the encouraging results to date, UPS management has approved the expansion of the program to include:

- Ten more prototype engines to be built within the next six months for further development work, durability testing, emissions evaluation, and road test.
- The procurement of patterns, castings, tooling, machining, etc., for a 500-engine field test evaluation in the UPS fleet.

This expanded program will allow dynamometer evaluation of the UPS 292 SC relative to emissions with a variety of fuels. Upon identification of areas requiring control to satisfy emission standards, hardware such as EGR, catalysts, and maximum fuel injection rate control will be evaluated to characterize the response of the engine to emission controls.

Work will continue in the areas of: Fuel economy evaluation, noise control, durability evaluations, performance testing under various climatic conditions, design and evaluation of retrofit components, formulation of service information and procedures, procurement of components and machining for the additional engines, and the installation of some of these engines in test vehicles.

Conclusions

In 30 months, the UPS TCCS engine program has proceeded from the planning stage to the prototype engine installation in a vehicle with preliminary testing completed.

No major engine or component design problems have been experienced to date.

The projected benefits of increased fuel economy, lower emissions, low noise level, reasonable cost, and broad fuel tolerance associated with the Texaco Controlled-Combustion System, appear to be entirely viable at this stage of the program.

Performance evaluations of the UPS 292 SC engine have revealed that starting, idling, acceleration, and general driveability on both gasoline and wide boiling range fuels are very satisfactory and equal to or better than the standard engine.

Fuel economy tests have shown better results than expected in parcel delivery operation cycles.

Noise levels are higher than the standard gas engine, but much lower than a comparable diesel engine.

Preliminary idle emission levels, monitored according to state test procedures, show low CO and HC levels.

Contacts with various component suppliers and machine shops have established that additional prototype and production components can be obtained and produced at reasonable costs.

The successful performance of the prototype engine in a package van and the prospect of saving fuel at the refinery while meeting noise, emissions, costs, and operational criteria have influenced a further expansion of the program to include more prototypes and a preproduction run for field evaluation.

Significance of the UPS 292 SC To National Petroleum Supplies

A great variety of power plants propel commercial and private road vehicles in this nation. These power plants require fuels with carefully selected properties, ranging from diesel fuel on the one hand to leaded and unleaded gasolines on the other.

The refinery processing required to meet these fuel characteristics wastes our limited petroleum supply.

Concerns about automotive emissions have added to the drain on petroleum resources as devices designed to control certain emissions reduce the fuel efficiency of engines.

The UPS 292 SC employs technology that could be applied broadly in any transportation field. It would be possible to use such engines in private passenger vehicles as well as in the heaviest of trucks.

This kind of power plant uniformity would make it possible for refineries to produce a wide boiling range fuel useable in any vehicle so powered. More wide boiling range fuel can be refined from a barrel of crude than any current automotive fuel.

High octane or cetane rating is not critical to the proper functioning of the UPS 292 SC. The production of fuels with high octane and cetane ratings consumes extra crude at the refinery, crude that otherwise could be converted into transportation use.

The UPS 292 SC, or any engine designed with the same technology, holds the promise of giving America more miles of transportation from a barrel of crude.

It is in the national interest that the technology incorporated into the UPS 292 SC be considered the basis for new engine construction in the years ahead.

Tests have shown that the UPS 292 SC performs with the efficiency of a diesel engine of equivalent horsepower, and in addition offers the advantages of lighter weight, less noise, lower manufacturing and maintenance costs and use of a fuel that is more refinery efficient.

The UPS 292 SC also is a clean-burning engine that will require little if any ancilliary equipment to meet emission standards.

This engine offers a petroleum-short world advanced technology that promises to greatly reduce the drain on



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limited reserves of oil. It also has the future advantage of being capable of using alcohol, synthetic, shale or other fuel derivatives with great efficiency.

The UPS 292 SC is a proved response to the quest for greater efficiency in the consumption of petroleum.

Engines that are being put on the road today will be powering commercial vehicles through the turn of this century. If the multifuel engine has the merit that United Parcel Service has come to believe it has, then the quickest possible conversion of single-fuel engines to multiple fuel capability should be attempted.

At the risk of being repetitive, such an engine will save our petroleum supplies at the refinery as well as on the road.

We are submitting Appendix A, which is a representative list of queries we have received from companies and individuals who have expressed interest in this project. Publicity on this engine has been relatively light, yet we have received an exceptional volume of mail from professional operators of commercial vehicles. This can be considered a gauge of unfulfilled need.

We also are submitting Appendix B, which is a compilation of comments about this project from responsible automotive engineering sources. This indicates the extent of support for this technology among professionals.

We respectfully call your attention to a Canadian program wherein sales tax relief is granted to purchasers of vehicles that function on nontraditional fuels.

United Parcel Service and Texaco have made strenuous efforts to acquaint the professional engineering community with the advantages of the multifuel engine. We submit as Appendix C the most recent paper on this project presented before the Society of Automotive Engineers.

But there is also a role here for government, and these hearings constitute a responsible beginning by the legislative branch, which has the power to modify whatever laws are necessary to encourage widespread use of this type of technology.

United Parcel Service thanks the committee for its interest in this stratified engine project, and stands ready to assist the committee in any future efforts to assess the viability of the concepts contained in this testimony.

(Note: Appendix B, "Engine of the Future," from Commercial Car Journal, December 1980, and appendix C, SAE Technical Paper Series No. 801429 of the Society of Automotive Engineers, Inc., have been retained in subcommittee files.)

APPENDIX A

## INTEREST EXPRESSED IN THE UPS 292 SC

| Firm/Individual | Type of Concern |
|---|---|
| GAF Corp. | Fleet leasing, general inquiry |
| Colonial Car Lease Co., Worcester, Mass. | Information |
| Rochester Truck Rental | Fleet leasing, general inquiry |
| Burson-Marsteller, New York City | Information |
| Rentnil Leasing, Akron, Ohio | Fleet leasing, general inquiry |
| Ontario Research Foundation | Request for engine to test methanol |
| Gelco Fleet Services, Eden Prairie, Minn. | Fleet leasing, general inquiry |
| Elwood H. Hillis, House of Rep., Indiana | Congratulations on project |
| E.M. Tharp, Inc. Porterville, Calif. | Truck Repair |
| ITEL, San Francisco, Calif. | Fleet leasing, general inquiry |
| Illinois Dept. Administrative Services | Information |
| Watkins Leasing, Norcross, Georgia | Fleet leasing, general inquiry |
| Phillips Petroleum Co., Bartlesville, Ohio | Research & development, alternate fuel test engine |
| General Leaseways, Davenport, Iowa | Fleet leasing, general inquiry |
| Minneapolis Public School, Minneapolis, Minn. | School bus fleet |
| Wheels, Inc., Chicago, Ill. | Fleet leasing, general inquiry |
| James Snow, Ministry of Transp. & Comm., Toronto | Testing |
| National Car Rental, Minneapolis, Minn. | Fleet leasing, general inquiry |
| U.S. Air Force, Norton AFB, Calif. | Ground support vehicles, test |

| Firm/Individual | Type of Concern |
|---|---|
| Blessings Corp., Piscataway, New Jersey | Diaper service, 450 vehicles, test |
| Entenmanns, Inc., Bayshore, New York | Bakery fleet, 800 vehicles, test |
| Consolidated Freightways, Menlo Park, Calif. | Fleet leasing, general inquiry |
| Rooks Transit, Inc., Grand Rapids, Mich. | Fleet leasing, general inquiry |
| Robert Lagomarisino, House of Rep., Calif. | Information |
| Yabut Lines, Inc., Manila | Fleet leasing, general inquiry |
| Larry Ogden, State of Vermont Energy Office | Information |
| Frito-Lay, Inc., Dallas, Texas | Fleet, general inquiry |
| Bob Jarvis, Member of Parliament, Ottawa, Canada | Interest in testing |
| Bill Bradley, U.S. Senate, New Jersey | Information |

Mr. OTTINGER. Thank you.

We have been joined by the distinguished chairman of the full Commerce Committee in the next Congress, my friend and colleague, John Dingell, from Michigan.

Mr. DINGELL. Thank you, Mr. Chairman. No questions. I am delighted to be here.

Mr. OTTINGER. My initial reaction, reading and hearing the testimony, that you might want to address, particularly Mr. Tessieri and Mr. Holtgreive, "If you are so smart, why aren't you rich?"

If this engine is indeed so good, why has it not been picked up by the auto manufacturers of the United States and around the world? I wonder if you might relate to us your experience in dealing with those manufacturers.

Mr. HOLTGREIVE. I basically feel the reason the engine is in the state it is today is the fact that we have had over the past years a low fuel cost and they are not really, as the general public, concerned about the fact that the petroleum-based products are going to have an end some day.

I think people are normally resistant to change. I think that as they become more conscious of our reserves, the limits to the reserves we have in petroleum base, and as the cost of fuel increases, the justification for this type of engine is going to be plainly visible, which is going to encourage this type of technology in the future.

Mr. OTTINGER. I understand that you had some specific experiences in trying to persuade various manufacturers to show an interest in this. I wondered if you would relate those, either Mr. Tessieri or Mr. Holtgreive.

Mr. HOLTGREIVE. I have talked to some of our current customers who use gasoline and diesel engines, and they say that it's a nice thing to be working on, but as long as they can get fuel, reliably get fuel at what they consider reasonable cost, I think they are going to say, "Keep me informed. As soon as you get something really ready to go on the market, let me know," when in reality——

Mr. OTTINGER. What is the actual experience saving on the fuel bill? Mr. Browne or Mr. Fisher.

Mr. FISHER. I beg your pardon?

Mr. OTTINGER. What are your actual experience savings on your fuel bill?

Mr. FISHER. On methanol?

Mr. OTTINGER. Yes.

Mr. FISHER. Well, we have not accumulated the actual statistics on the savings yet. Our experience at the moment, with our courier pickups on methanol, and comparing them to a gasoline counterpart, is that the courier pickup takes a third of a gallon more to go the same distance.

We look at the price differential between methanol and gasoline, and we are not too ashamed of that.

Mr. OTTINGER. That price differential now is what?

Mr. FISHER. Well, it will vary depending upon the source. We haven't paid more than 98 cents, and we have paid as low as 88.

Mr. OTTINGER. Mr. Browne, what is your experience?

Mr. BROWNE. We have not converted it into dollars. We have been more concerned about the fuel economy results——

Mr. OTTINGER. What are the fuel economy results?

Mr. BROWNE [continuing]. And the multifuel capabilities.

Mr. OTTINGER. You say it is in the city 38 percent. That has to translate to a lot of money.

Mr. BROWNE. Yes, sir. The interesting thing is the vehicle does better in the stop-start delivery methods that we use than it does on regular highway driving.

Mr. OTTINGER. That is what makes me incredulous. If you are getting a 38-percent fuel saving, you have been using gasoline—with gasoline at its present prices, one would think any commercial user, to the automobile companies themselves, would be tremendously advantageous.

Mr. Tessieri?

Mr. TESSIERI. Mr. Ottinger, we certainly have published over the years, so that everybody interested in this technology has known about it, and indeed there were specific efforts being made by some companies in Detroit in the late sixties, after the successful Army conversion, to look at this concept for possible adaptation.

It was about this time also that fuel costs started to increase so that their attention was increased. But it was also at that time when Detroit was required on a relatively short time frame from their standpoint to meet emission targets.

Early in the game those emission targets were not clearly defined. So they were aiming at a moving target, and that frankly took all the attention from the technology side that they had to spend.

There is no doubt in some of the smaller companies——

Mr. OTTINGER. Your engine solves the emission problem, doesn't it?

Mr. TESSIERI. Our engine is a clean engine. As a raw engine, it does make a contribution to that. The targets that they visualized and had been discussed at that time were such that Detroit said they were going to have to put add-on devices on the engines they already had in order to meet the standards if would have to put them on a new engine, why should they switch engines at the time since it would take so much effort just to develop those catalytic mufflers.

Today, with the controls they have, the three-way catalyst muffler, the computer they have to put on it, it would take a great deal of effort. So, they backed away on that basis.

Mr. OTTINGER. Is that chart correct, that you could meet even the toughest standards of California even without the catalytic converter?

Does it in fact meet the automotive standards without a catalytic converter?

Mr. TESSIERI. No. The hydrocarbons are high.

Mr. DINGELL. I am very interested in this. We have to be very clear. We have two standards here we are dealing with. One is the automotive standard, which is fixed at one level. The other is the light-duty truck standard, or is this heavy-duty truck? Which does this fall into?

Mr. HOLTGREIVE. The military programs were in the light-duty truck class. I believe the Postal Service vehicles would be in the heavy-duty class. United Parcel, excuse me.

Mr. DINGELL. UPS, are these heavy- or light-duty?

Mr. BROWNE. Mr. Lewis?

Mr. LEWIS. Jim Lewis, automotive engineer, UPS.

These would be 10,000 pounds or above, which would be considered in the heavy-duty class.

Mr. DINGELL. These are in the heavy-duty truck class.

Mr. LEWIS. I would like to qualify our results you see here. Right now UPS and all other carriers subject to various State emission rules are only subject to a tailpipe test. You bring your vehicle into the inspection station and they check for CO and hydrocarbons. These test results that you see here, the UPS engine, are tested in that fashion, and we have listed down here the three States that have such test procedures.

Mr. DINGELL. For heavy-duty trucks?

Mr. LEWIS. That is right. These should not be construed as to the Federal standards. These have nothing to do with the Federal standards. A 1965 UPS truck, brought into an Oregon inspection station, has to be under 250 parts per million of hydrocarbons.

Mr. DINGELL. Under 250 parts per million?

Mr. LEWIS. That is right.

Mr. DINGELL. An automobile, as I remember, would be 3.4, is that right?

Mr. LEWIS. I don't know what Oregon's is.

Mr. DINGELL. An automobile under Federal would be 3.4—3—3.4.

Mr. TESSIERI. Hydrocarbons are 0.41 grams per mile.

Mr. DINGELL. Seven would be the carbon monoxide and the nitrogen oxides would be what?

Mr. TESSIERI. Presently at 1 gram per mile, sir.

Mr. DINGELL. But waived up to 2 grams?

Mr. TESSIERI. For diesel applications.

Mr. DINGELL. I think it is 1.5 now.

Mr. HOLTGREIVE. Those are the automotive standards.

Mr. DINGELL. Yes. Can you tell us what these figures would be in terms of automotive? You are giving us quite different figures.

Mr. LEWIS. That is the point we want to make sure you obtain here. Right now, if you own a car in New Jersey—that is one I am familiar with——

Mr. DINGELL. If you own a truck in New Jersey.

Mr. LEWIS. These happen to be passenger car standards in New Jersey and California.

Mr. DINGELL. Passenger cars?

Mr. LEWIS. Yes, sir. If you bring your passenger car in, you have to have it under 200 parts per million, and you have to have it under 2 percent carbon monoxide. The only State right now that UPS or anybody else that I know of has to bring a truck in to check is Oregon. So, these are heavy duty and these are light duty. We put these here for comparison purposes.

Right now, just for an example, if we take a 1965 vehicle which was prior to any stringent requirements as far as emissions, we still have to show at least under 250 parts per million, and under 2 percent.

Now, if we take that engine out of that vehicle and put in our stratified charge engine, we take it back to the same station, we are now down here at 0.05 percent and 115 parts per million of hydrocarbons. You have actually cleaned up that vehicle by installing this new engine.

Now, true, it doesn't meet the Federal standards because we have not done any work in that area. This is just a first look at a raw engine that was only 6 months old, to see where it stood as far as engines that we have in the fleet.

I just want to make that point. This is a State test, not a Federal test.

Mr. DINGELL. If you want to make it meet the Federal requirements, you would have probably put a catalytic converter on the back end. Isn't that the mechanism you would add?

Mr. LEWIS. I believe that is what will be necessary, but the problem that we face, as Mr. Browne pointed out, we are not in the engine business. We are looking at a conversion for existing vehicles.

The point we would like to make here today is that although we have an exemption from the EPA to go ahead and look at 10 engines, as soon as 2 year's exemption is over, we have to convert those engines—destroy them or convert them back to their original form.

If you look at the economics of that——

Mr. DINGELL. Only EPA could come up with that.

Mr. LEWIS. I didn't hear you, sir.

Mr. DINGELL. I thank the gentleman.

Mr. OTTINGER. Mr. Tessieri, I understand that you also attempted to market the engine with various foreign manufacturers. Can you tell us what your experience is there?

Mr. TESSIERI. I would ask Mr. Tierney, who has made those trips, who is the project manager for the engine, to respond to you, sir.

Mr. OTTINGER. Would you identify yourself for the record, Mr. Tierney?

Mr. TIERNEY. I am William Tierney, project manager, automotive engine developments, for Texaco. I am located at our research center in Beacon, N.Y. In our contacts with the foreign manufacturers, we have had active interest from Daimler-Benz. Their point basically was, as mentioned before, that here is an engine that will run on a wide-boiling-range fuel. If the petroleum industry has a wide-boiling-range fuel available to market, then the engine is a viable thing. But with diesel fuel and gasoline, at the time that they made that decision, at relatively low cost, as Dr. Tessieri mentioned, there was no drive to bring out a new device. That decision was some 5 years old. The situation has changed drastically, and at the present time, of course, they are caught up in this situation of trying to live with and extend their current technology.

Their drive has been in the United States to appreciably increase the proportion of their imports that are diesel now in order to get fuel economy for their fleet. They started out with the 2.4-liter diesel. They followed that, to get improved performance, with the 3-liter diesel, which is the five-cylinder engine. And at the present time for a combination of emissions and performance they have turbocharged that 300. This has been an involvement of theirs from the standpoint of manpower. Our TCCS version of their engine is sitting in the wings. It is available. It is a matter of where to go from there.

Mr. OTTINGER. What about the Japanese? It is always a concern of ours that the Japanese not pick up an improvement like this, beat our ears additionally in the very important automotive field.

Mr. TIERNEY. The Japanese, Mr. Chairman, are doing the same thing the bulk of the Europeans are doing. They are in the position at the present time, because of their small car manufacture, to address the American market with what the American manufacturers are beginning to produce. That is the smaller car. That is the thrust of their operation. I might say that from the standpoint of acquainting them with what our system was, in the 1971–72 period, Texaco at its own cost manufactured 20 engines that incorporated our technology, and these were distributed to four manufacturers in Japan. That is Isuzu Mitsubishi; Nissan, which is Datsun; and Toyota. In Europe, we supplied an engine to Saab, to Daimler-Benz, British Leyland, and Fiat. The intent of this was to let them become familiar with what our TCCS was. This again was at the time that Dr. Tessieri mentioned, just prior to the action in response to the Clean Air Act Amendments of 1970, when all new projects were dropped and everybody had to go gung ho on the U.S. emissions standards and a new driving cycle, get the equipment, and convert to new standards for emissions not the parts per million that UPS talks about on the truck, but at grams per mile, which said a little engine whose exhaust system is dirtier on parts per million comes out cleaner on a grams per mile than a big engine whose parts per million are low but its displacement is large.

So I hesitate to use the word artifact, but it comes into my mind. It is an artifact of our emissions standard procedure. A dirty little engine is better than a real clean big one.

Mr. OTTINGER. Dr. Tessieri.

Mr. TESSIERI. Let me comment. We are going back, and properly so, to examine the scenarios that we faced at that time. We are indeed uniform here in the cost of fuels and the constraints that were faced as being important to us. It takes a gamble over a period of time for new technology to be adapted. That is what you are aiming for. That is what you are reaching for, I know. I believe if we come up to today, that we indeed are in the mode now that I believe the atmosphere is right to build the bridge, that was referred to to get us into today's fuels, into what we face tomorrow. The fact that UPS is running, and is getting good, hard, data and as we get additional engines in the fleet, this type of data bank that is going to be built up is going to be the one that sells the technology. The engine is out now performing. I believe we are over those little humps that we met time and again and were a barrier to the application of the technologies.

Mr. OTTINGER. What has been your experience in trying to interest the U.S. Government in purchasing these engines?

Mr. TIERNEY. The reference was made in the White engine testimony. Let me turn it over to Bob.

Mr. HOLTGREIVE. The effort that was applied on the contracts with the U.S. Army was on the L-163S engine addressed to the current on tactical vehicle. The purpose of that obviously was to provide multifuel capability. As I mentioned in my presentation, the Government, the U.S. Army, had decided to look at the commercial vehicle, and downplayed the requirement for this type of an engine. As a result, it has been canceled. The Government also—the U.S. Army, I should say, also had a little different priority on fuel. Their objective was to have the engine with the primary fuel being diesel fuel. The alternate fuel would have been gasoline. I think today's discussion is addressing ourselves to the methanols, the fuels made from coal; so really we are talking about a completely different ball game. In my opinion the engine, with the TCCS combustion system, although it runs well on diesel fuel, I think the performance does improve as you start moving into the blends of gasoline and that type of fuel. First of all, it burns cleaner; it is easier to meet the emissions certification requirements and things of that type.

So it is the "all-fuel" capability that I think brings us to—today's attention versus when the Government, the Army trucks——

Mr. OTTINGER. Is there interest by the large vehicle users? Has there been any interest on behalf of the large vehicle users of the Government, GSA, the Post Office?

Mr. HOLTGREIVE. I think when you start comparing this engine to the heavy-duty diesels used in the transportation system, the fuel-economy improvements being noticed by the United Parcel Service, are compared to a gasoline engine, not a direct injected diesel. The advantages of the engine in terms of fuel economy I would say are comparable to an indirect injected diesel; and I think the point here is not so much of running on diesel fuel in the future; we are going to try to run on methanol. I think the heavy-duty diesel is going to have to come up with some invention that can do that. As long as they can run on diesel fuel, in the heavy-duty transportation system, they are obviously running with a very economic powerplant.

Mr. OTTINGER. What about the potential for passenger-car use?

Mr. HOLTGREIVE. My feeling?

Mr. OTTINGER. Yes.

Mr. HOLTGREIVE. I mentioned in my presentation that the 1977 Gremlin car was converted to this engine. I said Texaco optimized that engine. In all fairness, about 3 to 4 months was spent on trying to get that engine as clean as possible with regards to emission standards before it was sent to the Bartlesville Test Center. Tests were run on many different fuels. If you look at the data in the report they prepared, the vehicle gets close to meeting the automotive emissions standards when the engine is running slightly derated and when it is running at different ignition timing characteristics. My basic feeling is we have not in any stretch of the imagination come to the point where that engine has been optimized, depending upon what fuel we are talking about.

The emission optimization, was really the last thing to be accomplished. We had to get the engine designed, functionally demonstrate its reliability, its fuel economy, its performance, its multifuel capability, followed by emissions studies after we decided what fuel was going to be the primary fuel.

Mr. OTTINGER. Mr. Fisher.

Mr. FISHER. I was going to comment on the preliminary emissions tests we made on the methanol cars.

The Ford Courier pickup—I would like to preface this comment with the fact that the manufacturer guarantees in writing to meet California standards, 1985 standards, which I believe are 250 parts per million hydrocarbon emissions.

The 1979 Courier, the Ford Courier, running on methanol, tested at 5 parts per million hydrocarbon emissions against 250 parts per million standard. The CO emissions tested at 0.02 as opposed to a standard of 1.25. In effect the cars running in Los Angeles are running like vacuum cleaners, because the air down there is dirtier than that.

Mr. OTTINGER. Has the EPA done any testing on the methanol fuel yet?

Mr. TESSIERI. Not that I know of, sir.

Mr. HOLTGREIVE. Not to my knowledge.

Mr. OTTINGER. They were not involved in the Bartlesville testing?

Mr. HOLTGREIVE. I do not believe so.

Mr. OTTINGER. Are present EPA requirements hindering the introduction of these engines? I take it they certainly are? What about other applications?

Mr. TESSIERI. Certainly the rigors of the Clean Air Act and the timetables that the Administrator received from that act, if you go through it—and I have recently read it again—there are not many places in there which recognize innovation, that allow innovative things to come into the system. As reported by Tom, it was difficult to even try to get a few engines to evaluate.

So I think in the long term with new systems and new fuels that we are facing, emissions ought to be reexamined in terms of new technology and fuels. From that standpoint, yes, in the future it could have an impact.

Mr. LEWIS. Mr. Chairman, could I make a comment, please?

Mr. OTTINGER. Yes.

Mr. LEWIS. I would like you to consider the retrofit aspect, not only UPS, but hundreds of other fleets that have control over their fuels and have the expertise in their own garages to maintain different systems, over and above what the normal driver of a truck would have that owns just one.

Currently UPS uses about 75 million gallons of gas a year in these 35,000 vehicles that we run around with packages. If you took this 35 percent that we have here, just as a number, that amounts to 26 million gallons saved a year that is available now for other people to use. Then add to that the fact that we can now use some of these strange fuels that are coming on the horizon. Even right now we are being approached by various oil companies that have things called raffinate, cutter stock; these are not exactly waste fuels, but they are fuels that do not fit into the normal automotive transportation. We could get them today if we had the vehicles. That would make gasoline and diesel fuel available to the general public. As methanols and other syncrudes come on, we could move into these. That is fine. Everything is dandy. But here we are trying to come up with a conversion like this. We are faced with having to meet these stringent standards that get more stringent every year. The question is the year that we put that new engine in a vehicle, do we have to go through the whole certification that takes place that year? If so, the whole project becomes completely lost because we do not have that type of technology or the money to expend on that technology. We would like your committee to consider that there be some exemptions or some consideration made as this gentleman said, for innovations and possible bridge engines for the future.

Mr. OTTINGER. That certainly will be an item that we will pursue.

Yes, sir.

Mr. TIERNEY. Mr. Chairman, to add to this, and put it in terms as I see it, the EPA standards recognize only two engines. First, they recognize the gasoline engine and tout the—the diesel was touted for its fuel economy. In order to bring it in, it was in essence brought in in the general area of the Clean Air Act Amendments of 1977 as, in essence, an innovative engine. It has been around longer than the gasoline engine from the standpoint of history, but it did get the $NO_x$ waiver. Now, of course, it faces the problem of particulates. What that balance is going to be as far as regulation is concerned, we do not know. We know there are standards set which are awfully tough to meet. Our engine from a particulate standpoint follows the same experience as other engines in the diesel field, and that is that as you decrease—we call it the weight of the fuel. In other words, as you move lighter, from a distillate fuel like diesel down to gasoline, the particulates go down; but unfortunately for the diesel engine, this reduction in the gravity or the weight or the lightness or heaviness of the fuel actually is heading in the direction of improved octane number and degradation of cetane number. So a diesel engine cannot run on the gasoline that could ease that particulate problem. This engine can. The large-range fuel we are talking about is in simple terms about the equivalent of taking about 25 percent of the distillate fuel, like a diesel or home heating oil, and 75 percent of a naphtha-type gasoline fraction, mix the two of them, you have this material that UPS has picked and what Mr. Holtgreive talked about.

Mr. OTTINGER. Am I correct the methanol fuel would have a lower particulate emissions?

Mr. TIERNEY. Exactly. This was demonstrated by the Department of Energy in their tests on our Gremlin. I am sure that Bank of America is seeing this, too, if they have particulate data. It is zero in the methanol car.

Mr. DINGELL. Mr. Chairman, if you would yield briefly, I am very interested in the comments made by the last two witnesses. It strikes me that you ought to have some amplification of the comments in the record, because next year one of the questions that this subcommittee will be dealing with, and the full committee will be dealing with, is the Clean Air Act, and how we get innovative programs in order to give us the maximum in terms of efficiency, innovation, clean air, a rational balance, and a mechanism. If you would, at your convenience, give us additional submissions on the points just raised, I think it would be helpful to the committee.

Mr. BROWNE. We will be happy to do that, sir.

Mr. DINGELL. Particularly with the concerns you have with regard to how you bridge an engine of this kind onto the market, the difficulties you have with the EPA, and the problems you have in terms of moving this kind of technology forward. That is the kind of thing that has always concerned us. That would assist us greatly in our work next year. [See p. 97.]

Mr. OTTINGER. I did not fully understand the—what was said with respect to costs of conversion of existing engines to one that would accommodate methanol?

Mr. FISHER. Our average cost ranges from $1,710 on the methanol cars to about $2,275 on a van, a van-sized vehicle. However, our point here is that we expect—and I think past history has shown—that alcohol engines traditionally last longer, because the engines burn cooler. Lower hydrocarbon means less wear and lower maintenance. We expect to recapture that up-front conversion cost. If we get 1 year of extra life out of that engine, we more than offset that conversion cost.

Mr. OTTINGER. The cost of conversion seems high compared to what we were told in Brazil when we went down there. Are they doing something different?

Mr. FISHER. As I understand it, they do not increase the compression of the engine. I will let Mr. McCurdy answer that. He knows more about it than I do.

Mr. MCCURDY. Yes, sir. I have recently been down to Brazil and been interested in this particular aspect you are speaking of. You must realize that the costs of conversion that are included in the bank's cars represent tearing the car apart and putting it back together again in a different configuration, with increased compression ratios, stiffer suspension, bigger tanks, and material changes, changes to the fuel control also.

Now if this job were to be done on a production line, as it is in Brazil, you find that the increased costs, the incremental costs of an alcohol car over a gasoline-power car is minimal.

Mr. OTTINGER. What will that be?

Mr. MCCURDY. The Brazilian Ford, for instance, running on methanol, the manufacturers are required to produce pure-alcohol cars down there, costs $50 more than the gasoline-powered Ford.

Mr. OTTINGER. $50 more?

Mr. MCCURDY. Yes, sir. Even considering that methanol is a tougher technical problem to accommodate than ethanol is, it should run about $100, perhaps $150 incremental costs for a methanol-powered car over a standard gasoline car on a production-line basis.

Mr. OTTINGER. In producing your engine, assuming mass production, what is your estimated cost compared to the——

Mr. HOLTGREIVE. The cost to produce an engine with the Texaco control combustion system in comparison to a gasoline engine is effectively the cost to adapt the fuel injection system—which consists of a pump, a drive, injection nozzles—and whatever difference there would be in cost between the current ignition system and the high-energy ignition system which is currently required for the combustion system. I hate to put numbers on it, but a fuel injection system would run in the neighborhood of let us say $300, maybe; I am just ballparking that, for what it is worth.

Mr. OTTINGER. That replaces the existing one that is put in?

Mr. HOLTGREIVE. It replaces the carburetor. I hate to use numbers. It depends on if you are talking four-cylinder, or six-cylinder, eight-cylinder.

Mr. OTTINGER. I just want a ballpark figure, not something you would be held to.

Mr. HOLTGREIVE. I am just giving you ballpark numbers based on the current costs. Now if you are going to make reference to an engine that will run on methanol, I do not think we can make any statement, because we do not know right now what fuel injection system changes are going to be necessary, if any, over the pump that will currently operate on unleaded gasoline.

Mr. TESSIERI. Sir, one thing on the Brazilian situation. There was an involvement with the government supporting some of the development, and I believe they supported some of the capital required in the car. So the final cost as it came out did deal with a car that they wanted to sell, because they wanted to enhance that alcohol car. Our contacts with the Volkswagen people in Brazil indicated they had a longer program which had some support.

Mr. OTTINGER. The thing that seems to be coming out, though, is that in production, if you are going to do this, your penalty in terms of price of the automobile is not significant whether it is $50, $100, or $300, with the additional mileage that you get. The displacement of gasoline and imported oil if you go to methanol gives advantages there that are just overwhelming. That is really what I was trying to get at, not specific figures, but the order or magnitude you are talking about is such that any additional costs of the engine would be made up within a very brief period of time.

Mr. Browne, did United Parcel, have they done any experimentation with electric cars?

Mr. BROWNE. Yes, we have. As a matter of fact, for many years we ran an electric fleet in Manhattan. I do not know how many vehicles we had, but it was substantial. As our business changed over the years and the weight of the packages became heavier, the electric would no longer do a day's work.

We did have a year-long experiment in conjunction with the University of Alabama on an electric delivery van. It was not as successful as we had hoped. We are currently operating in Manhattan and continuing to study, but it would appear from what we can learn that it is going to be a few years before there is battery capability for a commercial delivery vehicle.

Mr. OTTINGER. How do the costs come out on the electric vehicle?

Mr. BROWNE. I do not know, sir.

Mr. OTTINGER. If you have that information, we would be interested in getting it.

Mr. BROWNE. All right.

Mr. OTTINGER. Yes, sir.

Mr. MCCURDY. Mr. Chairman, since we are talking about innovation and we have brought in the subject of the electric vehicle, thinking a little further to the future, it should be pointed out that the ultimate electric vehicle will not be solely battery powered, but there will be an onboard power supply which will effectively charge the vehicle as it goes along.

Now a fuel cell appears to be the logical way to do this. Experiments are being conducted now at Los Alamos which would use, in the end, a methanol-fueled fuel cell in order to power the electrical vehicle. This is one of the longer-term advantages of methanol as an automotive fuel, because it works not only in the case of the internal combustion engine very nicely, but also with the electric car very nicely.

Mr. OTTINGER. I would like to just go back a minute to the chart you had up originally with the various barrels. You do not have to get the chart, but my recollection was that using normal fuels, you said you came out with a 15-percent savings using the stratified charge engine, not methanol. And using just the stratified charge engine with broad cut fuels, you got a 15-percent saving in the refinery crude that actually was necessary to drive the same number of miles; is that correct?

Mr. TESSIERI. That is correct, sir.

Mr. OTTINGER. So that ought to transfer, if it were used universally, into something like a 30-percent saving in imported oil?

Mr. TESSIERI. We have a direct comparison, for example, with the unleaded gasoline case. That comparison says 23 percent for that specific case; yes. So that is in miles per barrel of crude.

Mr. OTTINGER. That in itself ought to provide a substantial incentive, about $20 billion a year, Mr. Hunt calculates.

Mr. TESSIERI. It is a substantial change in what you are doing to that barrel of crude to deal with the sophisticated fuels we are dealing with today. We do not have to run for those process octanes we did in unleaded. That 23 percent comes from there. The material as it comes out of that crude barrel can be used in the engine. You do not have to massage the molecules very much.

Mr. OTTINGER. I hope our distinguished chairman would carry that message back to his home district. It seems to me that is a very exciting development.

Mr. Hunt, do you have any additional questions?

Mr. HUNT. Thank you, Mr. Chairman. Yes, I do.

Mr. Fisher, I understand that the majority of the methanol vehicles you are working with at this point are Ford-manufactured vehicles; are they?

Mr. FISHER. Yes. In fact, all of them are Ford vehicles.

Mr. HUNT. Have you considered using General Motors vehicles under any circumstances, or any other manufacturer? Why have you centered on Ford?

Mr. FISHER. Yes. For example, we use many Chevrolet Citations in our fleet because they are one of the better, small American cars being manufactured today; reliable; mileage is a little better than the smaller cars in the past that have been produced. Ford cooperates with our manufacturer on the specifications for conversion. That is what I have been told. We would like to have the Citation converted because we drive several hundred of those in our fleet.

The electronic fuel system for the Citation is very, very complex; our manufacturer has been unable to get the specifications. If he could obtain the specifications for the fuel system, he could convert it.

Mr. HUNT. Mr. Fisher, you might be interested in knowing there is a conversion program going on at the Solar Energy Research Institute with respect to the Chevy Citation. You might be able to get the required engine profiles and data from them.

Mr. McCurdy?

Mr. MCCURDY. That is another very interesting point. At the Solar Energy Research Institute the Citation that is being converted is converted into an engine of even more programs in some respects than the TCCS that we talked about, which might be 10 or 15 years out in the future, within the normal development process. In that particular engine, the methanol is being dissociated thermally by using the heat of the exhaust into low-medium Btu gas. Medium Btu gas is then used as a fuel. That has intrinsically 20-percent higher energy content than the basic fuel. Of course, the energy came from the exhaust itself. We are aware of that Citation experiment being done there, but it is not quite the simple conversion that we are thinking of when Mr. Fisher mentions the possible better cooperation from General Motors with the manufacturer of these methanol cars, modifier of these methanol cars.

Mr. FISHER. I would like to make another comment. There is another reason that Ford products are used in our conversion process. Basically, it is that the engine block is made of cast iron and rated for higher compression than many other engines; but we think that the little Citation V-6 is an excellent application, and are continuing to push to have it converted. Hopefully we can attain that. The Ford block also has five main bearings which add strength to the engine. To get efficiency out of methanol or alcohol fuels, you need that high compression.

Mr. HUNT. The block you are using is the 2.3-liter, straight four?

Mr. FISHER. Yes.

Mr. HUNT. Thank you, Mr. Fisher.

Mr. OTTINGER. Mr. Barrett.

Mr. BARRETT. Right now, Mr. Fisher, the methanol you are using is produced from natural gas?

Mr. FISHER. That is correct.

Mr. BARRETT. That methanol has no sulfur problem, I assume.

Mr. FISHER. No.

Mr. BARRETT. What happens if you have methanol produced from coal? Are you going to have the sulfur problem?

Mr. TESSIERI. As you well know—you visited, I believe, the Montebello Laboratory, in which the gasification process Texaco is dealing with is under development. In that particular process you capture the gases during the gasification process, and you can clean them up. You remove the sulfur from the gas before it goes into making methanol. So you do not carry that sulfur over. It can be cleaned up.

Mr. BARRETT. So it is a relatively sulfur-free product?

Mr. TESSIERI. Certainly. The chemical materials that are being used here, I am sure, meet the chemical specifications which would be extremely low in sulfur.

Mr. BARRETT. Again, Mr. Fisher, can I ask you what assistance have you received from the State of California in this project.

Mr. FISHER. Well, we received the assistance thanks to the good efforts of Representative Boatwright, who is now Senator Boatwright, from Walnut Creek, and Charles Stone, who I believe actually wrote the bill—A.B. 1401—which actually legalized the use of alcohol fuels in California effective January 1, 1980. That enabled us to work under California law to demonstrate the vehicle program we have going today.

Mr. BARRETT. You mentioned 15 percent by 1995 as a possible goal. Are you suggesting that a 15-percent methanol mix might be a good working ratio?

Mr. FISHER. I would defer that to Mr. McCurdy.

Mr. MCCURDY. In mentioning 15 percent by 1995, we came up with that figure only through consideration of what is a feasible-looking kind of production base increase, production factor, methanol plant program, if you will.

Mr. OTTINGER. You are not talking about a 15-percent mix?

Mr. MCCURDY. No, sir. Let me get directly to that question. That does not mean that we would use 15 percent methanol in gasoline, because the market will be a very complex thing in that time. It will have perhaps degraded hydrocarbon fuels out there; will have some good hydrocarbon fuel, comparable to today's; will have also cars which will run on methanol; will have cars that run very similarly to today's. Essentially what is required is a marketing system or device which will enable the customer to choose the kind of fuel that is appropriate to his car. That is what we have been doing with the blend program at the bank.

In other words, our blending pump is a flexible, at-the-station device which will enable the customer to come up and buy, if you will, 2 percent, 4 percent, 8 percent, 12 percent, or 18 percent. That is in the current configuration. That may not be the percentages that the market would eventually demand; but if in fact methanol blends survive the market test, what you should be able to do is to take either your methanol car into the service station and get the appropriate blend or your current automobile into the service station and get the appropriate blend. You can have 100-percent methanol, or any variety, variation in between.

If you have an engine such as the Texaco engine, it is going to be relatively insensitive to the kind of fuel that is used, but there will be a vast difference in the kinds of emissions that come out of even a Texaco engine. The point that Mr. Tierney made a bit ago about the heavy fuel versus the light fuel may, in fact, be resolved to some extent by being able to blend the heaviness of the fuel that is required to meet emissions standards with your particular engine.

Mr. OTTINGER. Mr. Hunt.

Mr. HUNT. Mr. Fisher, Mr. McCurdy, any other members of the panel, what do you consider to be the major constraints from the standpoint of moving faster? Is it the physical and material limitations in terms of pipes, steel valves, and so forth to manufacture methanol and methyl fuels. Is it the insufficient capacity of engineering firms to design and build methanol plants? Are there not enough of them around? Can we not open coal mines fast enough to far exceed the 15-percent level you are speaking of?

Mr. MCCURDY. Well, on a first-order cut, in order to—and this is, incidentally, Mr. McCurdy speaking, not the Bank of America that is replying to this particular question, because they have not had the opportunity to review this in depth.

On a first-order cut, to replace all of the gasoline used in this country in a year with methanol would require 100 large plants; and the problem is, how do you come from the state today where we have no large plants to the state where we have 100 large plants, or more realistically a mix of relatively small and medium-sized and very large plants?

Mr. HUNT. A large plant is what size?

Mr. MCCURDY. It produces maybe 50,000-barrels-a-day oil equivalent, something on that order. All of it is transportation fuel, which is probably the salient point in using methanol for transportation, because the efficiency of conversion is not so good as it is projected to be with some of the other coal processes that convert coal into a synthetic crude oil.

Mr. HUNT. That is basically a steel limitation or a capital limitation?

Mr. MCCURDY. Yes, sir. As Mr. Fisher testified, there will be a tremendous requirement for capital. Any rules or regulations which might open up the capital market for investment in plants of this scale would certainly be welcomed, I think, throughout the industry, because there are people in the country today that are willing to take on the large investment that is required in the coal-from-methanol plant; that is, a plant on the order of a billion dollars, only on the basis of better depreciation allowance and better investment.

Mr. HUNT. Mr. McCurdy, I think we will be receiving some testimony this afternoon that will indicate that the capital cost per barrel stream day of a methanol plant is running in the neighborhood of $10,000 up front. Considering there is a 20-percent investment tax credit, that brings the investment level down to roughly

$8,000-per-barrel stream day. I note that Litton Industries is promoting floating plants now at the cost of—this is a ship hull, including all the requisites to go onboard a sea-going methanol plant—in the neighborhood of $14,000-a-barrel stream day. So we may differ on the cost of the capital associated with the design and building of a methanol plant. We have seen some different figures I suspect than you have.

Mr. TIERNEY. If you do not mind, sir, I think there is one point that should be made. Those of us in the energy development business are fully aware of it, but for the clarification of those listening to the testimony—not yourselves, because I know you are aware of it—when we talk about drifting or moving from gasolines to alcohols and back and forth, people should be aware of the fact that the heating value of the alcohol is about half of that of the normal petroleum fuels. So that one does not take a carburetor or any fuel delivery system and just arbitrarily go from a gasoline to an alcohol and expect the same performance or go from an alcohol full-performance vehicle and not have to adjust the fuel delivery system, because then you are grossly overfueled if you go to the petroleum fuels.

Our point from the standpoint of our engine—and we feel it is a valuable point—is that while we are dealing in the general fuels of the petroleum type—these would be also the shale oils, the tar sands, the liquids from coals that might go into that kind of fuel—the engine has the transition capability, because going from gasoline to diesel fuel you are only talking about a 10-percent difference. I do not want people to be misled in their thinking that one can take an engine, either the one Mr. McCurdy is talking about for the Bank of America, or our engine, and just arbitrarily jump from alcohol to petroleum fuel. The engine will run on it, but it will not get the kind of performance you want. This is basically a technical project panel here. We tend to live with this. I just wanted to clarify the point.

Mr. HUNT. Thank you.

Mr. BARRETT. That is a good comment. Thank you.

Texaco offered Honda a test engine. Some time thereafter, Honda came out with its own stratified charge engine. Is it quite different from the Texaco model, or similar?

Mr. TIERNEY. Correction, sir. We did not offer Honda. It was—in Japan it was Isuzu, Nissan, Toyota, and Mitsubishi. The Honda stratified charge engine, and others that use this little precup in the gasoline type engine are again, in technical circles, we refer to this as torch ignited. It is a carbureted engine that has a small rich patch that the spark plug ignites. It has enough energy to go out and ignite a lean mixture. The Honda engine and engines of that type are, in fact, carbureted engines. They are not stratified in the sense that the fuel patch is locally and maintained locally richer than the rest of the main chamber. It had—the Honda has an octane requirement. It can operate on today's gasolines.

Mr. BARRETT. Could I ask the panel as a whole whether any of you would be opposed to a Government requirement that would require that future automobiles be capable of burning methanol or some mixture of methanol? Does anybody have any ideas on that?

Mr. TESSIERI. I would say that there are ways that can advance technology and its application other than a specific requirement, although Brazil certainly took this path. They made those cars and said a certain number of them would be utilized. I believe we have identified from demonstrations, from the California experiment, and certainly from the UPS data that we have here, a type of bridge engine which will go, given a chance to prove itself. I think one suggestion from White was that test fleets which would allow the further development of this engine and its applications would be an avenue the Government might take to help advance this technology. Bob may want to comment on this.

Mr. HOLTGREIVE. I agree with John. I think the technology would best come from requirements or by needs rather than by dictating that this has to be accomplished within a certain time period. I think that the results would probably be a little easier to accomplish and done with a little different—better—attitude; and I think when people recognize that we are looking at the future fuels, they may want to do this on their own, such as is being demonstrated by the Bank of America.

Mr. BARRETT. Thank you, Mr. Chairman.

Mr. OTTINGER. I want to thank you all for, really, very, very helpful testimony. We will be pursuing this, trying to overcome some of the barriers that you have indicated this morning.

We will leave the record open for 10 days for additional information that you want to submit, some of which has been requested. Again, sincerest thanks of the Chair for your very helpful contributions to our knowledge and indicating a path we might pursue to help us relieve our dependence on imported oil.

Mr. DINGELL. Mr. Chairman, I would like to join you in expressing the thanks of the committee. The work that the gentlemen are doing—all of you—is of great importance. All of you have made a valuable contribution. I want to express my particular commendations to the Bank of America and to UPS for the work you are doing. We have had questions concerning the difficulties in testing, testing permits, the ability to get an adequate number of these vehicles on the road from EPA, and certain other problems that we may have not identified this morning.

If you have identifiable problems with regard to EPA or other Federal agencies, with regard to the programs you are now entering upon, we would like to hear about them. We would like to communicate with them in a friendly fashion. Thank you very much.

Mr. OTTINGER. Some thanks ought to go to Peter Hunt and Mike Barrett of the staff, who have done a superb job in keeping after this.

[Testimony resumes on p. 156.]

[The following information was received for the record:]

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JOHN E. TESSIERI
VICE PRESIDENT
RESEARCH, ENVIRONMENT,
AND SAFETY

December 30, 1980

The Honorable John D. Dingell
Chairman of the Subcommittee on Energy and
Power of the Committee on Interstate and
Foreign Commerce
2221 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Chairman:

In response to the request during the Alternative Fuels and Engines Hearing of the Subcommittee on Energy and Power of the Committee on Interstate and Foreign Commerce on December 18, 1980, Texaco would like to offer comments on the question: What suggestions for modification of the Clean Air Act and associated regulations administered by the Environmental Protection Agency might be considered in order to permit the development and pursuit of innovative technologies that would be conducive to improved engines, vehicles, and the use of new fuels such as methanol? We request that these comments be incorporated in the hearing record. A copy is also being sent directly to Congressman Richard L. Ottinger.

Texaco has singled out the following four areas which in its judgment require legislative and regulatory change if the development of innovative engines with improved efficiency or new engine systems that can be operated by fuels from alternative energy sources are not to be seriously impeded.

- Provide exemptions from mandated Section 202 emission requirements of the Clean Air Act and from the EPA tampering regulations for development vehicles or test fleets. Such exemption should permit operation of a sufficient number of units for experimental and first generation testing of each type of technology.

- Provide simplified procedures for waiving mandated emission and tampering requirements for the advanced fleet testing of the innovative technologies. Such waivers should provide for protection of proprietary information and should be of sufficient duration so that the planned program can be brought to satisfactory conclusion. It is important that the waivers should ensure that test vehicles are allowed to operate for a reasonable useful life. Along these lines the government could assist in the development of new engine technologies or new fuels by participation in the testing and evaluation of these developments in its vast fleet of government vehicles.

- Provide a mechanism for setting appropriate emission requirements for production vehicles employing innovative engine technologies. This would ensure that high efficiency, low emission engines are not ruled out because they may not meet the exact mandated vehicle emission standards of the Clean Air Act which have evolved from emission levels achievable with conventional premixed charge internal combustion engines.

- Provide needed flexibility for emission and fuel economy standards in recognition of the fact that novel fuels, such as alcohols, have different technical and regulatory requirements as compared to petroleum derived fuels. For example; at present the Motor Vehicle Corporate Average Fuels Economy (CAFE) measurements on vehicle fuel economy are determined on a miles-per-gallon basis. Since alcohol has fewer BTU's per unit volume than does gasoline, alcohols (and the manufacturers of alcohol vehicles) would be penalized under the present procedures. However, on a miles per BTU basis, methanol and other alcohols are more efficient fuels than gasoline. Therefore, future CAFE measurement procedures should recognize these differences.

Additionally, technical problems with the Federal test procedures instrumentation as well as the extensive testing requirements for new fuels and fuel blending components seriously deter their development. These programs should be reviewed and simplified to make them more manageable. Particular problems lie in Section 5 of TSCA and Section 211(f) of the Clean Air Act. Texaco plans a further analysis of these difficulties in the near future.

With regard to methanol manufacture from coal, I am enclosing for the record copies of the following two technical papers:

- "Coal Gasification -- Why and Where Do We Stand" by G. N. Richter and W. G. Schlinger.

o "An Environmental Evaluation of The Texaco Coal Gasification Process" by W. G. Schlinger and G. N. Richter.

These papers include a survey of recent coal gasification technology as well as a description of environmental testing of the Texaco process. Also included is a press release which describes a joint Texaco-Houston Natural Gas Corporation proposal to use the Texaco process in the manufacture of methanol. Funds to assist in the feasibility study for this project have now been granted by the DOE (DOE Grant No. DE-GF01-80RA50337). A number of other projects using the Texaco Coal Gasification Process for power generation and for chemical manufacture are now in various stages of development.

In summary, certain requirements of current laws and regulations, particularly of the Clean Air Act, are serious deterrents to the development and demonstration of new and innovative technology for engines, vehicles, and alternate fuels. We respectfully request that the foregoing comments be considered in seeking legislative changes which will lead to appropriate balance in government agency regulations.

Sincerely yours,

John E. Tessieri

JOHN E. TESSIERI

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Enclosures

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NEWS FROM TEXACO INC.

## TEXACO AND HOUSTON NATURAL GAS PROPOSE FEASIBILITY STUDY FOR COAL GASIFICATION FACILITY IN LOUISIANA

FOR RELEASE: 10 A.M., EDST, MONDAY, APRIL 28, 1980.

WHITE PLAINS, N.Y., April 28. - Texaco Inc. and Houston Natural Gas Corporation (HNG) announced today they are seeking U.S. Department of Energy funding to study the feasibility of a 6,000-ton-a-day coal gasification facility to be located adjacent to Texaco's oil refinery on the Mississippi River at Convent, La. The joint Texaco and HNG effort is in response to the Energy Department's request for feasibility studies for alternate fuel production. Preliminary studies of the joint project were announced by Texaco and HNG last fall.

The feasibility studies would comprise separate proposals involving two plants. One would produce 300 million cubic feet a day of a medium-BTU synthesis gas. The second would utilize synthesis gas to manufacture 25,000 barrels a day of methanol.

The feasibility studies will also evaluate the potential for a modular expansion of the facility to produce an additional 300 million cubic feet a day of medium-BTU synthesis gas.

The medium-BTU gas or methanol could each be used either as fuels or petrochemical plant feedstocks.

Ebasco Services Incorporated has been selected as the engineering contractor to perform the feasibility studies, the companies said. These studies will require about 14 months to complete.

The proposed project would employ the Texaco Coal Gasification Process and would utilize coal provided by HNG.

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A 15-ton-a-day pilot unit of the Texaco process is in operation at Texaco's Montebello research laboratory near Los Angeles. A 150-ton-a-day plant using the process was started up in Germany in 1978. In another endeavor, final engineering design is underway on a 1,000-ton-a-day demonstration facility at Southern California Edison Company's Cool Water Generating Plant near Daggett, Calif., to manufacture synthesis gas from coal and to burn the gas in a combined-cycle power plant operation.

HNG, through its subsidiary Zeigler Coal Company, has nearly one billion tons of coal reserves in southern Illinois. Another HNG company, Federal Barge Lines, offers low-cost transportation of the coal through terminal and barge facilities on the Mississippi. A 15-million-ton-per-year coal transfer terminal is under construction at Cora, Illinois, and is scheduled for completion in 1980.

Texaco is the largest supplier of natural gas to industry in the State of Louisiana. It furnishes over 40 industrial customers with about 1.4 billion cubic feet per day of natural gas.

Texaco and HNG stated they are jointly contacting utilities and industrial gas consumers in Louisiana with the objective of enlisting their participation in the project either through an equity interest or as a purchaser of the syngas or methanol. There is a very high degree of interest among gas users in Louisiana, the companies said.

The use of the Texaco Coal Gasification Process, the companies stated, offers an environmentally acceptable way to utilize substantial quantities of coal, the nation's most abundant energy resource. "In addition to providing an assured supply of clean fuel, the coal gasification project will help reduce the growing U.S. dependency on foreign oil," Texaco and HNG said.

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04150

# COAL GASIFICATION

# WHY AND WHERE DO WE STAND?

by

W. G. Schlinger
Texaco Inc.
P. O. Box 400
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## ABSTRACT

Because of its versatility, coal gasification will have an ever increasing application in energy intensive operations in the United States by 1990. The gaseous product from coal gasification has many uses. The chemistry of coal gasification is relatively simple, however, equipment to carry out the gasification reactions in an efficient and environmentally accepted manner requires careful application of a wide variety of existing technologies. This requirement has led to a large number of gasification process developments. Only a few of these developments have reached what is known as the second generation stage of development and only a fraction of these will eventually reach a stage of full commercialization. Nevertheless, by the latter half of the 1980's, coal gasification will be supplying an ever-growing portion of the energy requirements of the United States.

PAPER NO. 2366

# COAL GASIFICATION
## WHY AND WHERE DO WE STAND?

by W. G. Schlinger

It is indeed an honor to be invited to talk about Coal Gasification to such a distinguished group. I have been involved in the development of processes for coal gasification for many years at Texaco's Research Laboratory in Montebello, California, the prime location of Texaco's coal gasification research and development activities.

## I. WHY

Why are Texaco, other private corporations, the Department of Energy, and the Electric Power Research Institute, to name a few, devoting so much effort and support to coal gasification today? The answer is clear. Coal gasification provides an extremely versatile technology for utilizing the vast energy reserves represented by the coal deposits contained in the world. It has been estimated that about 85% of the remaining fossil fuel energy reserves in the United States is represented by coal deposits. Furthermore, coal gasification provides a method for utilizing these energy reserves in an environmentally acceptable manner.

Some coal gasification processes can meet all present and projected environmental restrictions.

The desulfurized gaseous product from coal gasification has many uses. For example, the gasified product can be fed to existing steam boilers that are presently fired with fuel oil or natural gas. This gas can also be fed to existing and future gas turbines which could be coupled directly to large power generation equipment. In another application, the gaseous product is an alternate fuel for the many thousands of smaller process heaters and furnaces in the industrial complexes of the United States, including refineries and chemical plants. In other applications, the product gas from coal gasification which is also known as synthesis gas can be used as the primary feed source for much of the petrochemical industry in the United States, particularly the manufacture of such products as methanol, acetic acid, and complex alcohols. Naphtha or gasoline boiling range hydrocarbons and natural gas are presently the most common raw materials used as feed stocks for the petrochemical industry. Alternatively, syngas can be used to manufacture high purity hydrogen which can be used in the manufacture of ammonia or as the need arises for petroleum refining operations particularly as the crude oils available to domestic refineries become lower and lower in quality and hydrogen deficient. Syngas from coal can also be used in the metallurgical industry to reduce metallic ores to their native metals. Lastly, synthesis gas from the coal gasification processes is used in the Fischer Tropsch synthesis process to manufacture synthetic crude oil. This process forms the backbone of the coal liquefaction industry in South Africa.

II. <u>HOW</u>

Now that we have looked at some of the uses for the product from coal gasification, how is coal gasified? First of all, let us consider a few simplified chemical reactions involving the gasification of coal. I realize that many of you may have hoped you saw your last chemical equation many years ago, however, I am going to show you a few chemical equations in Figure 1. For simplicity, we will represent the chemical composition of coal as CH. This means that there is an atom of hydrogen associated with every atom of carbon in the coal. Of course, this is an obvious oversimplification because all coals contain considerable quantities of oxygen and most contain fairly large amounts of sulfur, smaller quantities of nitrogen and trace amounts of many other elements in the ash of the coal. Nevertheless, with the aid of these equations we can explain how it is possible to gasify coal. Complete combustion of coal with which you are all most familiar is represented by Equation 1. In this reaction enough oxygen is supplied with either air or pure oxygen to convert all the carbon to carbon dioxide and all the hydrogen to water. This reaction is highly exothermic which means there is a large amount of heat involved when this reaction occurs. The heat release is known as the heat of reaction of the coal and is represented by the enthalpy change which is expresed in BTU's per pound of coal gasified. The $\Delta H$ or heat release of this reaction is nearly 17,700 BTU's per pound of ash and moisture free coal. Alternatively, we may react coal with steam or water vapor to produce not carbon dioxide but carbon monoxide and hydrogen as shown in Equation 2. This reaction is endothermic meaning that heat must be supplied to the system in order to make this reaction progress. This reaction, therefore, has a positive $\Delta H$ and is shown as being a positive 3,770 BTU's per pound. Finally as shown in Equation 3 we may react coal with a limited amount of oxygen to convert the carbon to carbon monoxide and release the hydrogen as $H_2$ or elemental hydrogen. This reaction is mildly exothermic in that heat is released but the level of heat release is much lower than that associated with complete combustion. Finally the last column shows the net heat release if all the products of reaction are removed from the gasification system at 2500°F. You will note in the case of Equation 3 there is still some excess heat available. The conversion of the coal to carbon monoxide and hydrogen by reacting with a limited supply of oxygen can raise the temperature of the products to 2500°F. Most coal gasification processes then encompass a combination of these three reactions in such a manner that external heat or energy does not have to be supplied to the gasification system over and above that produced by the gasification reactions themselves. The appropriate combination of these reactions is the goal of nearly all of today's coal gasification process developments.

## III. TYPES OF GASIFIERS

Now let's talk about the type of physical equipment required for these gasification reactions to be accomplished on a large scale. Although there have been over 100 different coal gasification processes described in the technical literature, nearly all of the processes fall into three main categories. The first category is the fixed bed reactor, the second category is a fluidized bed reactor, and the third category is known as an entrained bed reactor. A fourth category may also be considered which is classified as the liquid or molten bath reactor. The three main categories are shown in Figure 2.

### A. Fixed Bed Gasifiers

The first and by far the oldest category, the fixed bed, includes both batch processes and continuous processes. Small fixed bed coal atmospheric pressure gasifiers date back to the 1830's. The use of these small units which produce as much as 10 million cubic feet per day of low BTU gas peaked in the 1920's when it was estimated there were 12,000 units in operation in the United States. Abundant supplies of natural gas and petroleum developed shortly thereafter and the number of units in operation declined rapidly. In other parts of the world, particularly England, Europe and South Africa the fixed bed gasifiers were used until well after World War II. The pressurized fixed bed reactor was first developed in Germany by Lurgi in the 1930's (1).

Basically the fixed bed gasifier involves the countercurrent contacting of coal and the oxidant be it air or oxygen. Coal is added intermittently to the top of the bed while the oxidant usually flows continuously from the bottom. Ash leaving the bottom of the reactor is withdrawn from time to time and the hot gases pass up through the coal bed exiting from the gasifier at temperatures on the order of 1000°F. It is necessary to limit the temperature at the bottom of the gasifier to a level of about 1900°F in order to avoid agglomeration of the ash to form clinkers. This temperature of course varies from coal to coal depending upon the chemical composition of the ash. It is customary to add a large amount of steam with the oxidant in order to control this temperature. Much of this steam passes through the system resulting in significant heat losses and extensive treatment of large volumes of water that are condensed from the gas. Typically, this water contains significant amounts of phenols and other oxygenated or partially gasified hydrocarbons.

Since the gas leaving the gasifier at 1000°F has been in contact with fresh coal, there are large amounts of vaporizable coal tar and other liquid products distilled from the coal and contained in this exit gas. These materials must be removed from the gas by suitable cleanup systems.

Significant improvements in the fixed bed gasifier systems have been achieved by operating the bottom of the gasifier at a temperature above the melting point of the coal ash and removing the ash as a molten slag. The higher temperature allows for increased coal throughputs and less steam contaminating the product gas. Atmospheric pressure fixed bed gasifiers with slagging bottoms have been operated in many parts of Europe. The development of a large pressurized slagging fixed bed gasifier is under way in Scotland (2). Nevertheless, the slagging fixed bed gasifier like the earlier dry ash version is still sensitive to the type of coal being gasified and requires extensive and expensive water and gas treating facilities.

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B. Fluidized Bed Gasifiers

The second type of gasifier, the fluidizied bed, offers some additional advantages over the fixed bed. The atmospheric pressure Winkler gasifier (3) which was developed in Germany in the 1920's was the first large scale commercial application of the fluidized bed concept.

The impressive success in the United States in developing the fluidized catalytic cracking processes for conversion of heavy distillate oils to gasoline immediately preceding World War II encouraged application of the fluidization technique for coal gasification. The fluid bed principle was employed in a number of research projects in the 40's and 50's and again in recent years.

In the fluidized bed operation carefully sized particles of coal are suspended in the gasification media by the upflow of the oxidant material. Here again the temperature in the fluidized bed must be controlled carefully so as not to exceed the agglomeration temperature of the coal ash or ash clinkers and slag will form which would cause serious interruptions in the operation. Fresh coal is added to the fluidized bed intermittently at the top of the reactor and spent coal or ash is withdrawn from the bottom. As in the case of the fixed bed reactor the gaseous flow is continuous. In the fluidized bed the solid material is well mixed and therefore one of the drawbacks of the fluidizied bed operation is the inability to achieve complete gasification of the coal in a single stage due to carry-over of fine carbon-rich particles and because the purge flow of ash withdrawn from the bottom of the reactor typically contains a significant portion of ungasified coal. However, several fluidized bed projects are now under way including the Cogas fluid bed gasifier in England, the Institute of Gas Technologies U-Gas (4) and Hygas (5) pilot ûnits in Chicago and the United States Department of Energy Synthane (6) process. Some of these gasifiers operate at pressures well above atmospheric.

C. Entrained Bed Gasifiers

The third category or the entrained bed gasifier offers a number of advantages over the first two, particularly when operating at temperatures above the fusion temperature of the coal ash. These advantages include the ability to process both caking and non-caking coal, delivery of a product gas free from tars and by-products, high throughput and high carbon conversion, particularly at high pressure because of the much more rapid reaction rates.

Entrained gasifiers involve bringing the oxidant and the coal into the gasifier in a concurrent manner in contrast to the counterflow techniques used in the first two types of systems. These gasifiers may operate in either an upflow or downflow manner.

The single stage oxygen blown atmospheric pressure Koppers-Totzek (7) gasifier is the only fully commercial entrained bed gasifier in operation today. A number of plants using this gasifier are in operation in Europe, Africa and Asia. The atmospheric pressure of this gasifier places it at an economic disadvantage for the majority of applications envisioned today. Most entrained gasifier developments involve pressurized reactors. A number of entrained bed gasifiers are undergoing development tests today in large pilot plants having a capacity on the order of 100 to 200 tons of coal per day. These include the single stage pressurized gasifier being developed by Shell and Koppers in Germany (8), the two stage Combustion Engineering gasifier (9), and the Department of Energy By-Gas gasifier (10) in Pennsylvania. The above gasifiers all employ a dry coal feed system whereas the downflow pressurized single stage Texaco gasifier (11), (12) uses a slurry of coal in water as the feed.

## IV. ALTERNATE GASIFIER CLASSIFICATION

Before describing some of these gasifiers in more detail, there is another classification which should be discussed. Coal gasifiers are typically called first, second and third generation processes. Today's three fully commercial gasifiers, the fixed bed Lurgi gasifier, the fluid bed Winkler and the entrained bed Koppers-Totzek are all classified as first generation processes. Gasifiers on which development work began more than five years ago are usually classified as second generation processes in that they offer some potential for significant improvement over the first generation systems. More recent developments which incorporate further improvements are usually classified as third generation processes. Alternatively, second generation processes may be considered as those that are currently being tested at a scale of more than 100 tons per day of coal feed.

## V. <u>TYPICAL GASIFIERS</u>

Figure 3 shows a cross-sectional view of the first generation dry ash Lurgi gasifier. You will note the coal bed is distributed and agitated by slowly moving mechanical stirrers. Oxygen and steam are admitted through lances in the bottom of the reactor and pass through the grate supporting the coal bed. As the coal particles burn they fall through the grate and are removed through the bottom of the gasifier. Typically, carefully sized coal with a minimum fines content is required for feed to this type of gasifier.

As mentioned earlier, the 1000°F gases leaving the top must be taken to rather extensive cleanup systems.

Figure 4 is a cross-sectional view of the first generation atmospheric pressure fluidized bed Winkler gasifier. This type of system has a number of drawbacks in that coal fines are frequently contained in the gas along with undesirable partially oxygenated or gasified hydrocarbon materials such as phenols and creosols. Again, carefully sized coal must be added to the reactor system and the spent coal must be periodically withdrawn through the bottom of the reactor. Because the coal bed is thoroughly agitated complete conversion is difficult as the particles withdrawn from the bottom of the bed typically contain considerable amounts of unconverted carbon. Figures 5 and 6 show cross-sectional views of the U-Gas and the three stage Hygas demonstration units which are also considered to be second generation fluidized bed processes.

The first generation Koppers-Totzek entrained bed gasifier is shown in Figure 7. This is an upflow entrained bed gasifier with the gasified coal leaving the top of the reactor. Slag is removed from the bottom through a water quench system. This unit operates at near atmospheric pressure and has several drawbacks in that it is difficult to scrub the particulate matter from the gas at low pressure and, of course, the gas must eventually be compressed before most end uses can be considered.

Koppers and Shell have joined in an effort to develop a pressurized version of the first generation Koppers-Totzek gasifier. A 150 ton per day pilot unit is presently in operation near Hamburg in Germany. Little is known about the actual design of this unit. However, it has been stated that operations are proceeding satisfactorily.

Combustion Engineering's two stage atmospheric pressure entrained gasifier is shown in Figure 8. This development is also considered to be second generation and tests are presently being conducted on the unit in Windsor, Connecticut.

The second generation Texaco downflow entrained bed gasifier (13) is also in operation in Germany with the 150 ton per day demonstration unit located in the Ruhrchemie chemical plant in Oberhausen, Germany. This plant is shown in Figure 9. The process utilizes a concentrated water slurry of carefully ground coal and oxygen as feed to the gasifier. The gasifier operates at a temperature above the slagging temperature of the ash and both slag and hot gases are removed from the bottom of the gasifier through a waste heat recovery system. The slag is separated, quenched in water and discharged through a lock hopper system while the hot gases are then directed through additional heat recovery equipment.

Some of the second generation coal gasification processes are nearing full commercialization. A number of evaluations and studies aimed at commercial applications of first and second generation processes have been made. Invariably these studies show that gas from coal can not economically compete with energy from natural gas and crude oil. However, recent price increases in crude oil obviously point to the fact that the cross-over point will be approaching us in the very near future. Conversion to coal can of course be hastened by Federal legislation such as the Fuel Use Act and such Federal assistance as special tax incentives.

Since the Fuel Use Act mandates the use of coal in new fossil fueled power generating stations and conversion to coal in existing units by 1990, gasification of coal for production of power may well be its first wide commercial application (14). To demonstrate that coal gasification can be used to generate power efficiently, Texaco and the Southern California Edison Company together with the Electric Power Research Institute and others have launched an effort to build a commercial size, 100 megawatt demonstration plant. This coal gasification combined cycle power plant feeding 1000 tons per day of coal will be located at Edison's Cool Water generating site in Southern California near Barstow. The plant will be the first of its type built in the United States and should pave the way for a new generation of power plants (15).

IV. FUTURE

We will look back upon the first half of the 80's as the time when the first major efforts were made to move coal into power, petrochemical and fuel gas generation in the United States. There is a large amount of technology available and it is apparent that clean energy from coal gasification will be able to compete economically with worldwide crude oil by the mid-1980's.

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| | HEAT OF REACTION BTU/LB OF MAF COAL | |
|---|---|---|
| | 60°F | 2500°F |
| $CH + 5/4\,O_2 \rightarrow CO_2 + 1/2\,H_2O$ | -17,600 | -14,500 |
| $CH + H_2O \rightarrow CO + 3/2\,H_2$ | 3,800 | 7,300 |
| $CH + 1/2\,O_2 \rightarrow CO + 1/2\,H_2$ | -4,200 | -2,100 |

FIGURE 1 COAL GASIFICATION REACTIONS

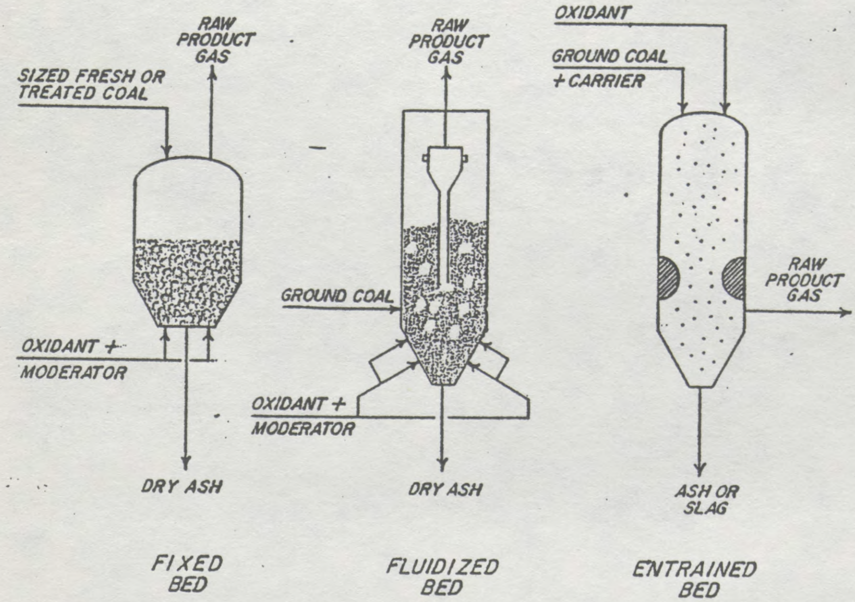


FIGURE 2 THE BASIC TYPES OF COAL GASIFIERS

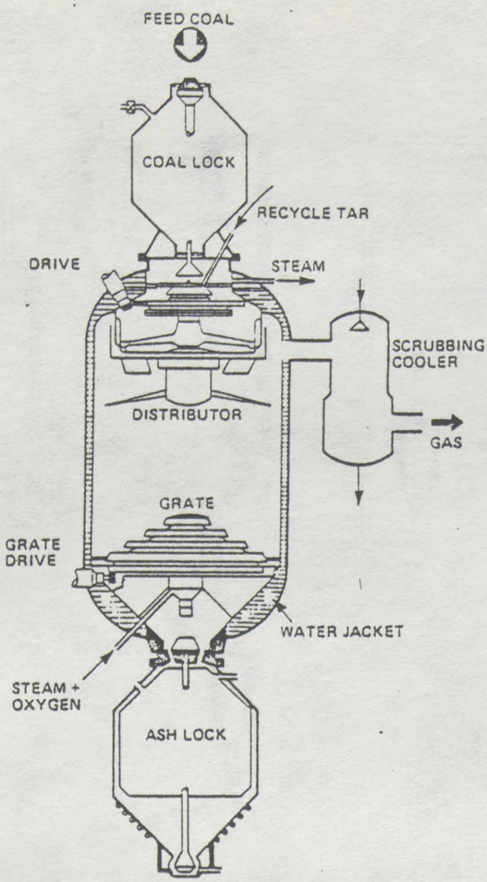


FIGURE 3 LURGI DRY ASH GASIFIER

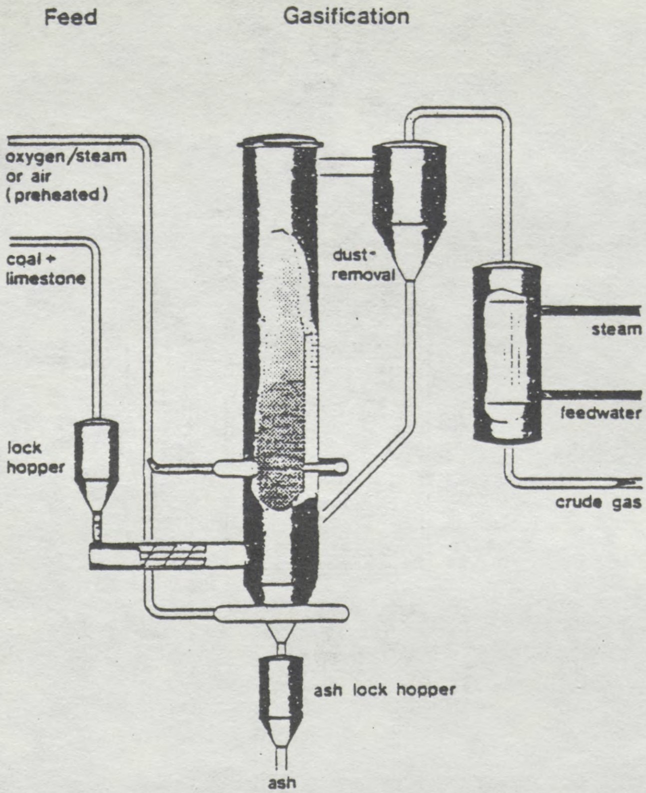


FIGURE 4 WINKLER FLUIDIZED BED GASIFIER

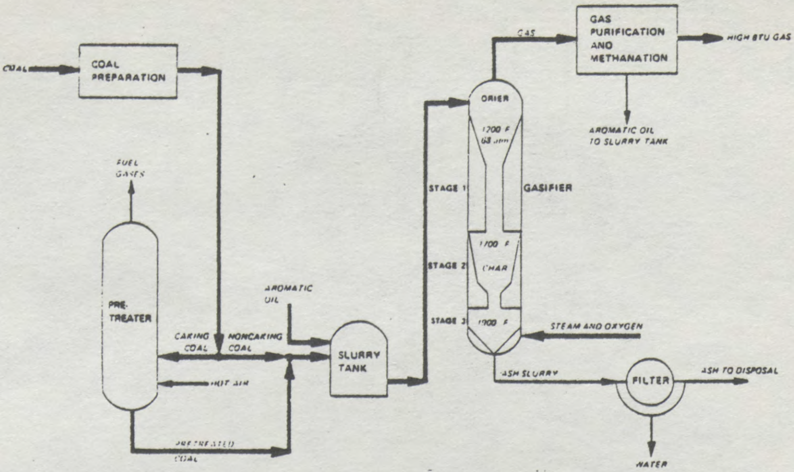


FIGURE 5 HYGAS PROCESS SCHEMATIC

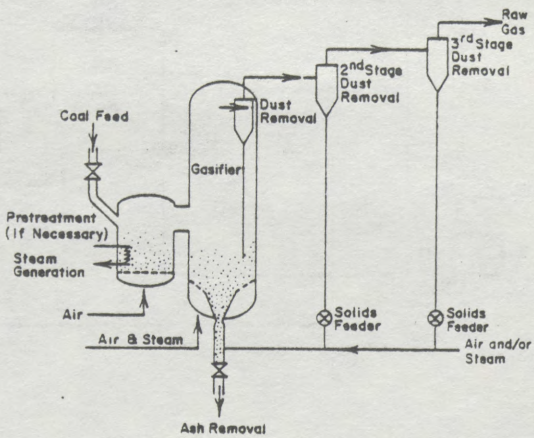


FIGURE 6 U-GAS OR AGGLOMERATING ASH GASIFIER

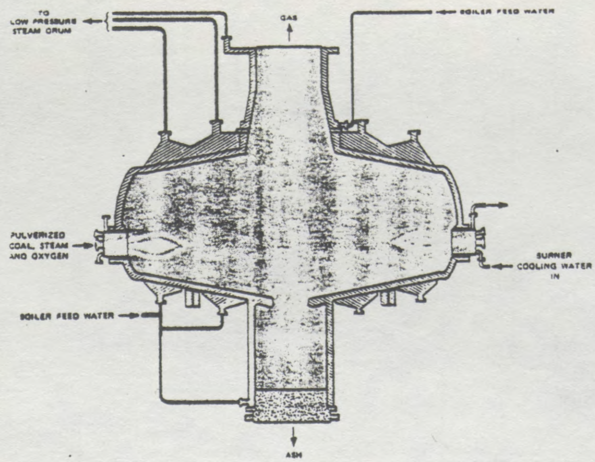


FIGURE 7 KOPPERS-TOTZEK TWO-HEADED GASIFIER

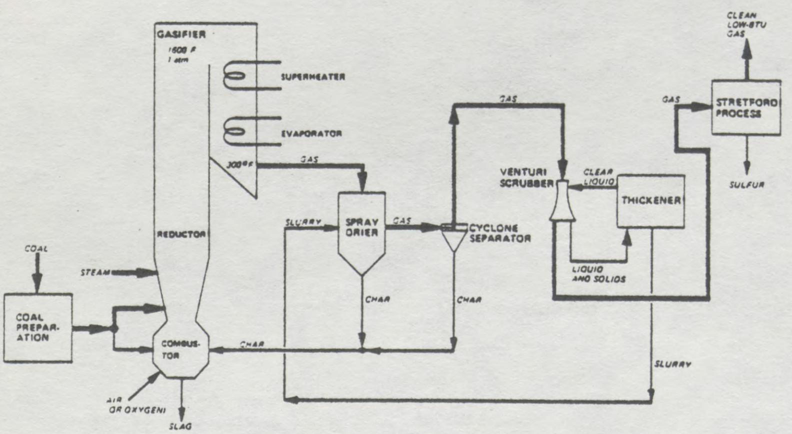


FIGURE 8 COMBUSTION ENGINEERING ENTRAINED BED GASIFIER

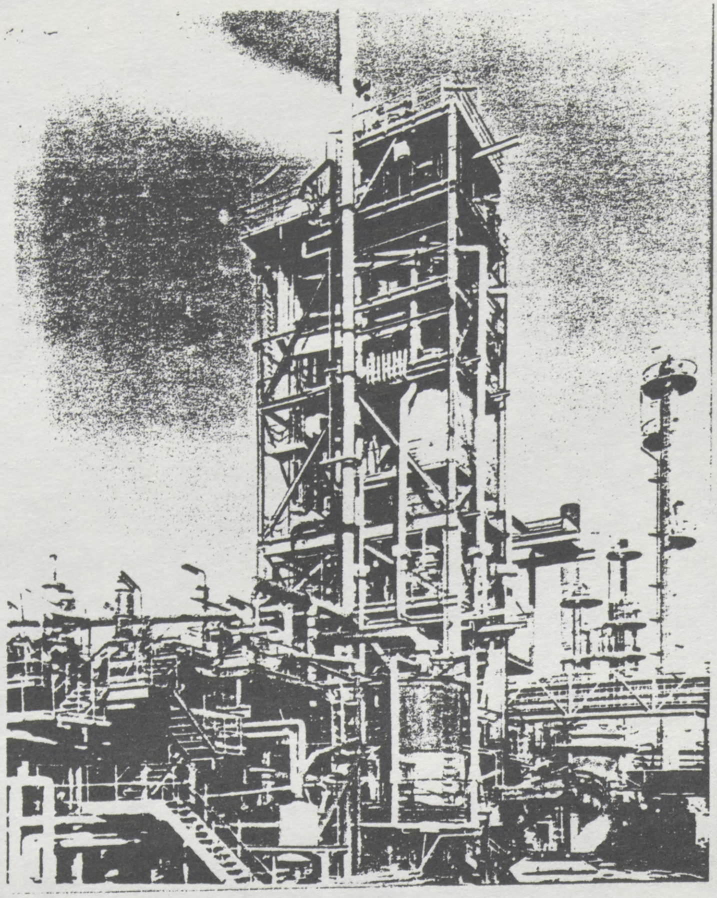

FIGURE 9 COAL GASIFICATION DEMONSTRATION PLANT AT OBERHAUSEN-HOLTEN

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# AN ENVIRONMENTAL EVALUATION
# OF
# THE TEXACO COAL GASIFICATION PROCESS

by

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# AN ENVIRONMENTAL EVALUATION OF THE TEXACO COAL GASIFICATION PROCESS

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## SUMMARY

After studying the three basic types of coal gasification processes, fixed bed, fluid bed and entrained bed, it is apparent that the entrained bed gasification processes create fewer by-products. Because of its superior environmental potential, the Texaco entrained bed down-flow gasifier has been selected for a number of projects. Careful measurements have been made on the low level contaminants contained in all the streams existing from a 15-ton per day pilot unit operating on either eastern or western U.S. coal. These measurements show that the anticipated contaminant levels from commercial coal gasification plants using the Texaco Coal Gasification Process will be very low and that the Texaco entrained bed gasifier can meet all present and anticipated environmental restrictions.

## INTRODUCTION

Many oil deficient industrialized nations in the world are actively establishing plans for alternate sources of energy to replace widespread use of imported crude oil. Work in this area is particularly active in South Africa, Germany, Japan and Australia, as well as the United States. A conflict between environmental concerns and the need to develop alternate energy sources has been a continuing problem. The proponents of coal fired power plants, coal gasification and coal liquefaction technologies have not been immune from attack by demands for strict compliance with established standards. These conflicts have significantly delayed the construction of commercial and commercial prototype plants, especially in the United States. This paper will be limited to a discussion of the gasification options available to those planning for utilization of coal as an alternate energy source and will dwell especially on the relationship between the type of gasification technology and the environmental acceptability of the process. Recently acquired environmental data obtained from the Texaco Coal Gasification process will also be discussed.

## TYPES OF GASIFIERS

Coal gasification processes can be divided into three major categories depending upon the type of gasifier employed (1). The three gasifier categories are the fixed or slowly moving bed, the fluidized bed and the entrained bed.

Fixed or slowly moving bed gasifiers generally operate in a countercurrent mode, so that the gases leaving the gasification zone lastly contact the fresh entering coal. These hot gases extract significant quantities of volatile material and partially gasified products from the fresh coal. In addition to the desired products from the coal gasification process, hydrogen, carbon monoxide and methane, the hot gases contain large amounts of tars, phenols, cresols, and other oxygen containing organic compounds. It is these components which are removed from the gas during cooling, water washing and condensation that cause most of the environmental problems associated with fixed bed gasification systems. Fixed bed gasifiers include most of the commercial gasifiers used in the world during the 19th and early 20th centuries. The system most often considered today is the pressurized Lurgi gasifier (2).

The fluidized bed concept was first used in the Winkler gasifier in the 1920's (3), and in this country today there are a number of recent coal gasification process developments (4) based on use of the fluidized bed gasification principle. In the fluidized bed system, carefully sized, fresh or pretreated coal is added to the reaction vessel and suspended by an upflow of oxygen, gasified products from the coal and other temperature moderators. The coal is gasified within the fluidized bed thus formed. As was the case with the fixed or slowly moving bed gasifier, the gases leaving the top of the fluidized bed are in contact with partially consumed and fresh coal. The gasifier temperature must be held below the softening or initial deformation temperature of the coal ash, typically, a temperature well below 1900°F. At this temperature, many undesirable by-products are relatively stable. Because of this contact, tars and partially oxidized materials are also produced in the fluidized bed gasifier. Again, removal and disposal of the by-products in the crude gasified coal poses a number of environmental problems in the fluidized system.

The entrained bed gasifier dating back to the 1950's (5), (6) is the most recent development and is distinguished from the two previous types by the fact that the oxygen and coal flow in a concurrent manner as opposed to the countercurrent flow of the previous two systems. Also, the entrained bed gasifier is normally operated at a temperature above the melting point of the coal ash. At this temperature, generally above 2300 to 2400°F, the gasification reaction rates are much faster and many of the undesirable by-products associated with the fixed bed and the fluid bed systems are unstable and are destroyed. When the entrained bed gasifier is operated at pressures substantially above atmospheric, high throughput and high single pass conversion can be obtained.

From this brief discussion, it is apparent that the entrained bed slagging gasifier offers one of the most promising gasification technologies for producing gaseous products from coal with a minimum of undesirable by-products. The Texaco Coal Gasification Process involves a pressurized, entrained bed, down-flow slagging gasifier (1), (6). The environmental information presented and discussed in this paper was obtained from a Texaco gasifier.

## THE TEXACO GASIFIER

At Texaco's Montebello Research Laboratory near Los Angeles, there are two 15 to 20 ton per day coal gasification pilot units. These pilot units have been operating on a wide range of coals and detailed environmental data have been accumulated on both an eastern coal, Illinois Number 6, and a western coal, Kaiparowits. A photograph of the pilot units is shown in Figure 1. These pilot units operate at pressures ranging from 300 to 1200 pounds per square inch.

A schematic flow diagram of the pilot unit used to accumulate the environmental data is shown in Figure 2. The dotted envelope delineates the process boundaries and defines the effluent and the feed streams. It is these streams that have been subjected to detailed environmental assessment.

The Texaco Coal Gasification Process involves the partial combustion with oxygen of a concentrated slurry of ground carbonaceous material in water. The gasification chamber reaction temperature is allowed to rise above the fluid temperature of the ash and the molten ash is quenched and collected in water. The ash removed from the lockhopper is separated into a coarse and a fine fraction. The coarse slag consists of glassy fragments varying from 1/16 to 1/2 inch in diameter and containing only 0.5 to 2 percent carbon. The fine slag generally contains substantially more carbon and is optionally recycled back to the gasifier. Alternately it can be discarded with the coarse slag.

The hot gas from the gasifier may be conducted through heat exchange equipment for cooling or quenched directly in water depending upon the end products desired. As shown in Figure 2, the water quench mode was used during the environmental tests described below. After cooling or quenching the gas, entrained fine particulate matter is removed by a water scrubbing system. At this point, the particulate matter in the gas is reduced to less than 0.1 milligram per normal cubic meter. Water condensed from the gas along with water removed from the quench chamber of the gasifier flows to a settler where the particulate matter is separated for recycle back to the coal slurry system and clarified water is recovered for recycle to the process. Since some water soluble material from the coal is added to the water circulating system, a blow-down stream must be extracted from this recycled water.

The cooled water scrubbed gas separated from the condensed water consists primarily of hydrogen, carbon monoxide, carbon dioxide and trace amounts of methane along with the sulfur that was present in the coal. This sulfur is contained in the gas as either $H_2S$ or COS. Because of the high temperature in the gasifier, only trace amounts of other hydrocarbon materials are found in this gas. Nearly all uses of this gas require removal of sulfur compounds. The level of reduction depends upon the process requirements as well as environmental regulations. In case the gas were to be used as fuel in a small process heater, a boiler or a gas turbine significant quantities of sulfur could be left in the gas and still meet air quality standards. On the other hand, use of the gas for chemical manufacture will require nearly complete removal of both $H_2S$ and COS. Depending upon the level of sulfur reduction required, several acid gas removal processes are commercially available. Most of these processes are based on physical absorption of the sulfur compounds rather than removal by chemical reaction. The gas recovered from the solvent during regeneration which contains the sulfur compounds removed from the product gas is routed to a sulfur recovery unit. This unit would traditionally be a Claus plant followed by a tail gas clean-up system. In the environmental tests conducted at the Montebello Research Laboratory, sulfur compounds were removed with a Selexol system.

TRACE COMPONENTS

Each of the entering and exiting streams from the pilot unit has been numbered in Figure 2 for identification. The properties of these streams will be discussed in the following pages. The coal water slurry is prepared from the fresh coal, recycle solids and water which may be obtained from several sources. The slag water that has been separated from the fine slag can be returned to the coal slurry, a portion of the blow-down water can be used for this purpose or fresh process make-up water can be used. Figure 3 contains the ultimate analysis of each of the two coals used for the study and Figure 4 is a 21 trace element analysis of each of the two coals. This stream is identified as Stream 1 in

Figure 2. The analyses of the three water streams in the two coal gasification cases are shown in Figures 5 to 8. Figures 5 and 7 contain water quality analyses of the three streams and Figure 6 and 8 contain the trace component analyses of the three streams for each of the two coals processed. With the exception of the components shown under trace organics in Figures 5 and 7, no other organics on the EPA Priority Pollutant List were found at detection levels ranging from 0.05 to 10 parts per billion (PPB).

Hot gases leaving the gasifier are quenched in the recirculating water system. This water extracts certain water soluble components from the slag and the gas stream and the dissolved solids in the circulating water system are controlled by the excess water discharge, Stream 6.

The slag and particulate ash components which accumulate in the bottom of this quench chamber are withdrawn through a water sealed lockhopper system at the bottom of this chamber. In order to minimize the quantity of gas dissolved in this water, the intermediate chamber of the lockhopper is filled with fresh water at the beginning of each cycle. Therefore, only small amounts of dissolved gas and water soluble components are removed through the lockhopper. Large particles; i.e., particles larger than approximately 1/16 to 1/8 of an inch are retained on the screen at the bottom of the lockhopper and constitute the coarse slag discharge from the process Stream 5. Fine slag and water passing through the screen can be either separated into a recyclable water, Stream 4, and a disposable slag, Stream 3, or the fine slag can be returned to the front end or coal slurry preparation system. These fused and solidified glassy particles are very inert to interaction with the ground water which may be associated with a slag disposal site.

Measurements of the composition and the trace elements in both the coarse and fine slag are shown in Figure 9. ASTM leaching tests using deionized water have been made on slag from each of the two coals processed. The water quality of the leachates recovered from the tests is shown in Figures 10 and 11. Tests were also made to determine the trace organic compounds in each of the two slag components. Results of these tests are shown in Figure 12.

Fuel gas is, of course, the main product leaving the gasification process. Measurements made on the fuel gas, Stream No. 7, are shown in Figures 13, 14, and 15.

It is apparent from studying Figures 3 through 15 that the Texaco Coal Gasification process exhibits a very low pollution level. The fuel gas stream contains a minimal number of by-products, most of the water streams are recycled within the process and the ash from the coal is recovered as a slag which exhibits very low levels of leachability.

## COMMERCIALIZATION

Because of the low pollution level and favorable economics of the Texaco Coal Gasification process, commercialization of the process is moving ahead rapidly. A 150 ton per day demonstration plant has been operating in the Ruhrchemie Petrochemical plant in Oberhausen, West Germany for more than 2 years (7). In addition, the Tennessee Valley Authority is in the final construction stages of a 150 ton per day plant designed to produce ammonia from coal in Muscle Shoals, Alabama (8). This plant will replace an existing facility using natural gas as the feed stock.

In July of 1979, Texaco and the Southern California Edison Company announced that they would work together to solicit additional participants and construct a 100 megawatt coal gasification combined cycle power plant in the Southern California high desert near Barstow (9). This "Cool Water Coal Gasification Project," shown in its conceptual stages in Figure 16, is moving ahead with substantial help from the Electric Power Research Institute. Detailed engineering design is in progress by Bechtel Inc. and it is projected that ground will be broken for the plant in early 1981.

In a recent announcement (10), Tennessee Eastman disclosed plans to convert their petrochemical plant in Kingsport, Tennessee to use coal rather than petroleum based stocks as the raw material source. This conversion will include installation of the Texaco Coal Gasification Process. It is apparent from these announced projects that the Texaco Coal Gasification Process has won wide acceptance as an environmentally acceptable means of producing clean gaseous products from coal.

## ACKNOWLEDGMENTS

The environmental data included in this report was acquired in test programs supported by the Electric Power Research Institute and the sponsors of the Cool Water Coal Gasification Project. Analytical testing was performed by the Radian Corporation and by Texaco.

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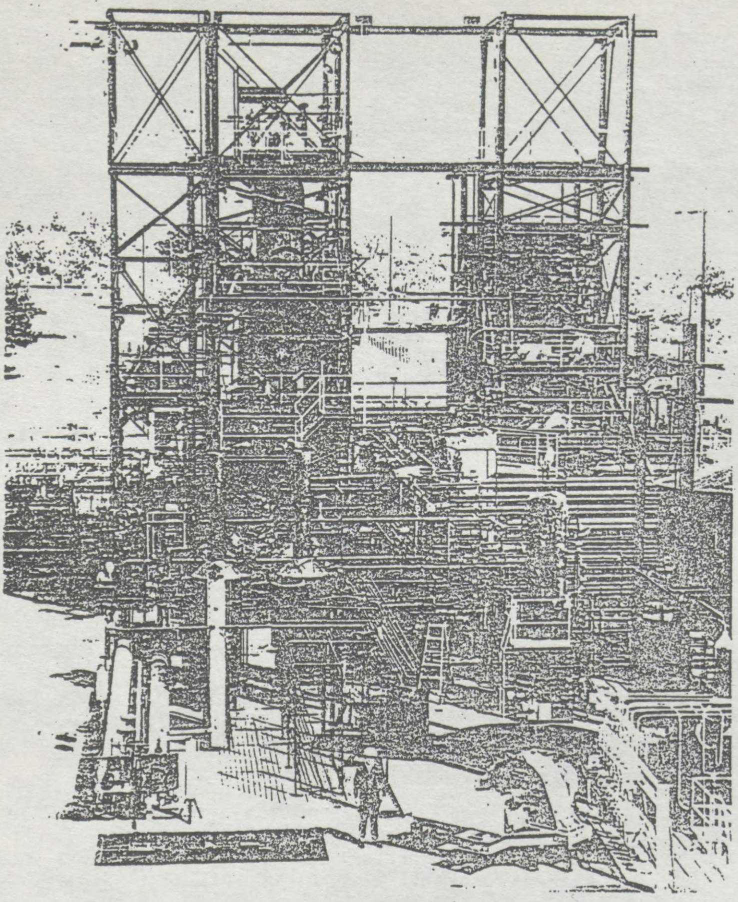

FIGURE 1

Texaco Coal Gasification Pilot Units

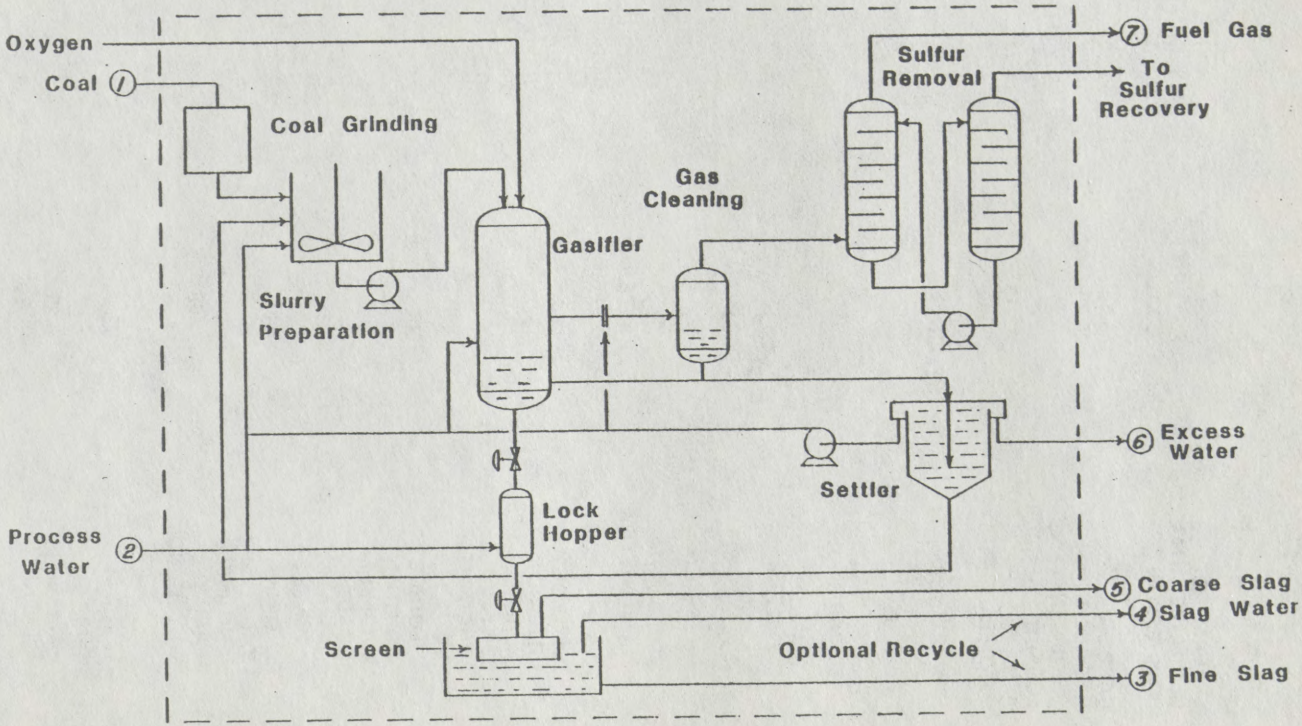


FIGURE 2

Schematic Flow Diagram
The Texaco Coal Gasification Process

## FIGURE 3
## COAL ANALYSES

| STREAM NO. | ① | ① |
|---|---|---|
| ULTIMATE ANALYSIS WT % (DRY) | EASTERN COAL | WESTERN COAL |
| CARBON | 65.56 | 67.80 |
| HYDROGEN | 4.76 | 4.72 |
| NITROGEN | 1.27 | 1.17 |
| SULFUR | 4.17 | 0.35 |
| ASH | 13.15 | 11.22 |
| OXYGEN (DIFF) | 11.09 | 14.74 |
| HHV (BTU/LB) | 11,736 | 11,707 |

## FIGURE 4
## COAL ANALYSES
## TRACE COMPONENTS

| STREAM NO. | ① | ① |
|---|---|---|
| ELEMENT, PPM | EASTERN COAL | WESTERN COAL |
| ANTIMONY | 1.2 | <0.5 |
| ARSENIC | 8.0 | <0.9 |
| BARIUM | 64 | 320 |
| BERYLLIUM | 0.6 | <0.2 |
| BORON | NR | 15 |
| CHLORINE | 602 | 24 |
| CADMIUM | 1.4 | 0.2 |
| CHROMIUM | 35 | 34 |
| COBALT | 5 | 0.9 |
| COPPER | 19 | 8 |
| FLUORINE | 96 | 65 |
| LEAD | 23 | 4.0 |
| MANGANESE | 95 | 34 |
| MERCURY | 0.08 | 0.1 |
| MOLYBDENUM | 8 | 0.3 |
| NICKEL | 55 | 3.7 |
| SELENIUM | 2 | 1.7 |
| SILVER | 0.2 | 0.3 |
| THALLIUM | 0.25 | 0.3 |
| VANADIUM | 25 | 14 |
| ZINC | 147 | 7.9 |

# FIGURE 5
## WATER QUALITY DATA
## EASTERN COAL

| STREAM NO. | (2) PROCESS WATER | (4) SLAG WATER | (6) EXCESS WATER |
|---|---|---|---|
| pH | NR | 8.0 | 7.7 |
| TDS, PPM | 0.0 | 355 | 1708 |
| CONDUCTIVITY | NR | 1650 | 7100 |
| COD, PPM | NR | 221 | 405 |
| TOC, PPM | <1 | 28 | 215 |
| AMMONIA, PPM | NR | 380 | 1270 |
| ANIONS, PPM | | | |
| BROMIDE | <1 | <1 | <1 |
| CHLORIDE | 29 | 146 | 740 |
| FLUORIDE | <1 | 31 | 175 |
| CYANIDE | NR | <1 | 8 |
| FORMATE | <1 | 94 | 522 |
| NITRATE | <1 | 3 | 9 |
| SULFIDE | 0.3 | 6 | 316 |
| SULFATE | 25 | 38 | 21 |
| THIOCYNATE | NR | 2 | 8 |
| THIOSULFATE | NR | 5 | NR |
| TRACE ORGANICS, PPB | | | |
| BENZENE | | <0.5 | 3.0 |
| TOLUENE | | <0.5 | 2.0 |
| ANTHRACENE | | 1.0 | 0.5 |
| FLUORANTHENE | | 2.0 | 0.5 |
| NAPHTHALENE | | – | 2.0 |
| PYRENE | | 0.6 | 0.7 |
| PHENANTHRENE | | 0.2 | 0.02 |
| PHENOLS | | NR | <10 |

FIGURE 6
TRACE ELEMENTS IN WATER STREAMS
EASTERN COAL

| STREAM NO. ELEMENT, PPM | ② PROCESS WATER | ④ SLAG WATER | ⑥ EXCESS WATER |
|---|---|---|---|
| ANTIMONY | <0.001 | .016 | <.001 |
| ARSENIC | 0.002 | .07 | .022 |
| BARIUM | 0.03 | .10 | .54 |
| BERYLLIUM | 0.0004 | .005 | .018 |
| BORON | – | – | – |
| CADMIUM | 0.010 | .003 | .003 |
| CHROMIUM | 0.002 | .003 | .006 |
| COBALT | 0.005 | .10 | .021 |
| COPPER | 0.01 | 0.017 | .010 |
| FLUORINE | <1 | 31 | 175 |
| LEAD | 0.005 | .045 | .054 |
| MANGANESE | 0.13 | .08 | .104 |
| MERCURY | <0.0001 | <.0001 | <.0001 |
| MOLYBDENUM | <0.02 | .03 | <.02 |
| NICKEL | 0.03 | .07 | .03 |
| SELENIUM | 0.005 | 0.033 | 0.010 |
| SILVER | 0.0006 | 0.002 | 0.002 |
| THALLIUM | 0.002 | .006 | .01 |
| VANADIUM | <0.04 | <.04 | <.04 |
| ZINC | 0.195 | .046 | .03 |

FIGURE 7
WATER QUALITY
WESTERN COAL

| STREAM NO. | (2) PROCESS WATER | (4) SLAG WATER | (6) EXCESS WATER |
|---|---|---|---|
| pH | 5.3 | 8.9 | 8.8 |
| TDS, PPM | <5 | 28 | 420 |
| CONDUCTIVITY | <10 | 410 | 10,800 |
| COD, PPM | <5 | 48 | 760 |
| TOC, PPM | 0.4 | 38 | 360 |
| AMMONIA, PPM | <1 | 130 | 2700 |
| ANIONS, PPM | | | |
| BROMIDE | <0.05 | <0.05 | <0.05 |
| CHLORIDE | <0.1 | 42 | 7.5 |
| FLUORIDE | <0.01 | <0.1 | 28 |
| CYANIDE | <0.2 | 0.4 | 11 |
| FORMATE | <0.1 | 56 | 1200 |
| NITRATE | <0.5 | <0.5 | 2.0 |
| SULFIDE | <0.5 | <0.5 | 61 |
| SULFATE | 1.3 | 5 | 47 |
| THIOCYNATE | <4 | <4 | 29 |
| TRACE ORGANICS, PPB | | | |
| PHENOLS | NR | 1.2 | 1.2 |
| UNIDENTIFIED | NR | 7.0 | 2.8 |

FIGURE 8
TRACE ELEMENTS IN WATER STREAMS
WESTERN COAL

| STREAM NO.<br>ELEMENT, PPM | (2) PROCESS WATER | (4) SLAG WATER | (6) EXCESS WATER |
|---|---|---|---|
| ANTIMONY | <0.001 | <0.001 | <0.001 |
| ARSENIC | <0.001 | 0.015 | 0.016 |
| BARIUM | 0.004 | 0.05 | 0.90 |
| BERYLLIUM | <0.001 | <0.001 | 0.002 |
| BORON | 0.2 | 0.3 | 1.4 |
| CADMIUM | <0.006 | <0.001 | <0.001 |
| CHROMIUM | <0.001 | <0.001 | <0.001 |
| COBALT | <0.001 | <0.001 | <0.001 |
| COPPER | 0.031 | 0.008 | 0.005 |
| FLUORINE | <0.1 | <0.01 | 29 |
| LEAD | <0.005 | 0.011 | <0.005 |
| MANGANESE | 0.002 | 0.003 | 0.024 |
| MERCURY | 0.002 | 0.002 | 0.002 |
| MOLYBDENUM | <0.001 | 0.003 | 0.015 |
| NICKEL | <0.01 | <0.01 | <0.01 |
| SELENIUM | <0.001 | 0.025 | 0.460 |
| SILVER | <0.002 | <0.002 | <0.002 |
| THALLIUM | <0.002 | <0.002 | 0.003 |
| VANADIUM | <0.01 | <0.01 | 0.03 |
| ZINC | <0.01 | <0.01 | <0.01 |

FIGURE 9
SLAG ANALYSES

| STREAM NO. | ⑤ | ④ | ⑤ | ④ |
|---|---|---|---|---|
| MAJOR COMPONENTS WT % | EASTERN COAL COARSE SLAG | EASTERN COAL FINE SLAG | WESTERN COAL COARSE SLAG | WESTERN COAL FINE SLAG |
| ASH | 99.30 | 65.14 | 99.91 | 81.52 |
| CARBON | 1.79 | 32.39 | 0.40 | 17.21 |
| HYDROGEN | 0.023 | 0.31 | 0.16 | 0.01 |
| NITROGEN | 0.06 | 0.48 | 0.08 | 0.26 |
| SULFUR | 0.83 | 2.08 | 0.0 | 0.09 |
| TRACE ELEMENTS, PPM (WT) | | | | |
| ANTIMONY | 0.9 | 0.9 | <0.5 | <0.5 |
| ARSENIC | 15.0 | 20.5 | 30 | 22 |
| BARIUM | 378 | 301.5 | 3200 | 2650 |
| BERYLLIUM | 7.5 | 6.6 | 2.2 | 2.3 |
| BORON | – | – | 63 | 40 |
| CHLORINE | 10 | 44 | 6 | 300 |
| CADMIUM | 5.0 | 6.7 | 0.32 | 0.40 |
| CHROMIUM | 1790 | 842 | 2100 | 1450 |
| COBALT | 125 | 85.5 | 13 | 9.7 |
| COPPER | 81 | 90 | 49 | 48 |
| FLUORINE | 45 | 210 | 80 | 230 |
| LEAD | 30 | 47 | 0.9 | 2.8 |
| MANGANESE | 614 | 525 | 380 | 300 |
| MERCURY | 0.15 | 0.095 | 0.18 | 0.28 |
| MOLYBDENUM | 64 | 98.5 | 2.3 | 7.6 |
| NICKEL | 229 | 267 | 39 | 34 |
| SELENIUM | 14 | 17.5 | 0.76 | 4.0 |
| SILVER | 0.1 | 0.2 | <0.3 | 0.6 |
| THALLIUM | 0.3 | 0.3 | 1.0 | 8.4 |
| VANADIUM | 340 | 280 | 180 | 140 |
| ZINC | 65 | 425 | 13 | 26 |

FIGURE 10
PROPERTIES OF DEIONIZED
WATER LEACHEATE
ASTM METHOD (PROPOSED)

| | EASTERN COAL COARSE SLAG | EASTERN COAL FINE SLAG | WESTERN COAL COARSE SLAG | WESTERN COAL FINE SLAG |
|---|---|---|---|---|
| pH | 6.0 | 7.1 | 9.6 | 8.9 |
| TDS, PPM | NR | NR | 250 | 310 |
| CONDUCTIVITY | 100 | 600 | 53 | 135 |
| COD, PPM | NR | NR | 45 | 28 |
| TOC, PPM | 2 | 3 | 15 | 9.1 |
| AMMONIA, PPM | 1.2 | 4.6 | NR | NR |
| ANIONS, PPM | | | | |
| BROMIDE | <0.1 | <0.1 | – | – |
| CHLORIDE | 1.5 | 2.2 | – | – |
| FLUORIDE | 4.9 | 8.7 | – | – |
| CYANIDE | < .001 | < .001 | – | – |
| FORMATE | <1 | <1 | – | – |
| NITRATE | 0.4 | 0.5 | – | – |
| NITRITE | <0.1 | <0.1 | – | – |
| SULFATE | 26.9 | 313 | – | – |

FIGURE 11
PROPERTIES OF DEIONIZED
WATER LEACHEATE
ASTM METHOD (PROPOSED)

| ELEMENT, PPM | EASTERN COAL COARSE SLAG | EASTERN COAL FINE SLAG | WESTERN COAL COARSE SLAG | WESTERN COAL FINE SLAG |
|---|---|---|---|---|
| ANTIMONY | 0.003 | 0.005 | – | – |
| ARSENIC | 0.007 | 0.019 | <0.01 | <0.01 |
| BARIUM | <0.38 | <0.38 | 0.04 | 0.2 |
| BERYLLIUM | <0.001 | <0.001 | – | – |
| BORON | – | – | – | – |
| CADMIUM | 0.004 | 0.0006 | – | – |
| CHROMIUM | <0.002 | 0.002 | 0.015 | 0.003 |
| COBALT | 0.029 | 0.028 | <0.002 | 0.001 |
| COPPER | <0.003 | 0.016 | 0.03 | <0.006 |
| FLUORINE | 4.9 | 8.7 | – | 9.0 |
| LEAD | 0.005 | 0.008 | – | – |
| MANGANESE | 0.105 | 0.212 | 0.002 | 0.03 |
| MERCURY | <0.005 | <0.005 | 0.01 | <0.002 |
| MOLYBDENUM | <0.9 | <0.9 | – | – |
| NICKEL | 0.875 | 0.131 | <0.02 | – |
| SELENIUM | <0.009 | 0.027 | <0.002 | 0.05 |
| SILVER | <0.002 | <0.002 | – | – |
| THALLIUM | <0.006 | <0.006 | – | 0.001 |
| VANADIUM | <1.8 | <1.8 | 0.14 | 0.16 |
| ZINC | 0.098 | 0.052 | <0.09 | <0.09 |

## FIGURE 12
## TRACE COMPOUNDS IN SLAG COMPONENTS

| STREAM NO. | (5) | (3) | (5) | (3) |
|---|---|---|---|---|
| COMPOUND*, PPB | EASTERN COAL | | WESTERN COAL | |
| | COARSE SLAG | FINE SLAG | COARSE SLAG | FINE SLAG |
| NAPHTHALENE | ND | ND | 150 | 240 |
| ALKYL NAPHTHALENES | NR | NR | ND | 191 |
| PHENANTHRENE** | 12 | 610 | 230 | 18 |
| ACENAPHTHENE | ND | ND | 10 | 21 |
| FLUORENE | ND | ND | 15 | ND |
| PYRENE | 45 | 800 | 23 | ND |
| ANTHRAQUINONE | NR | NR | 210 | ND |
| FLUORANTHENE | 63 | 840 | NR | NR |

* NO OTHER COMPOUNDS ON THE EPA PRIORITY POLLUTANT LIST DETECTED.
** INCLUDES ANTHRACENE

ND = NOT DETECTED

NR = NOT REPORTED

## FIGURE 13
## FUEL GAS COMPOSITION

| STREAM NO. | (7) EASTERN COAL | (7) WESTERN COAL |
|---|---|---|
| MAJOR COMPONENTS, VOL % | | |
| HYDROGEN | 36.8 | 36.2 |
| CARBON MONOXIDE | 44.5 | 44.4 |
| CARBON DIOXIDE | 18.2 | 18.7 |
| ARGON | 0.09 | 0.16 |
| NITROGEN | 0.18 | 0.36 |
| SULFUR SPECIES, PPM (VOL) | | |
| HYDROGEN SULFIDE | 1300 | 520 |
| CARBONYL SULFIDE | 200 | 32 |
| METHYL MERCAPTAN | – | <1 |
| ETHYL MERCAPTAN | – | <1 |
| DIMETHYL MERCAPTAN | – | <1 |
| CARBON DISULFIDE | – | <1 |
| HYDROCARBONS, PPM (VOL) | | |
| METHANE | 28 | 570 |
| ETHANE | <.1 | <1 |
| ETHYLENE | <.1 | <1 |
| ACETYLENE | <.1 | <1 |
| PROPANE | 0.9 | <1 |
| PROPENE | <.1 | <1 |
| BUTANE | <.1 | <1 |
| PENTANES | <.1 | 6 |
| HEXANES | <.1 | <1 |

## FIGURE 14
## TRACE COMPONENTS IN FUEL GAS STREAM

| STREAM NO. | (7) EASTERN COAL | (7) WESTERN COAL |
|---|---|---|
| **COMPONENT Mg/SCM** | | |
| AMMONIA | 3.5 | <0.5 |
| FORMATE | 64 | NR |
| CYANIDE | 0.03 | 7.2 |
| THIOCYNATE | <0.1 | NR |
| CHLORIDE | 23 | NR |
| FLUORIDE | 4.4 | <0.02 |
| NOx | <0.002 | <0.001 |
| **TRACE ELEMENTS, μg/SCM** | | |
| ANTIMONY | <0.2 | <0.2 |
| ARSENIC | 2.1 | <0.2 |
| BARIUM | 25 | 3 |
| BERYLLIUM | 0.14 | <0.2 |
| BORON | NR | 0.7 |
| CADMIUM | 2 | <0.2 |
| CHROMIUM | 2 | <0.2 |
| COBALT | 1 | 1.6 |
| COPPER | 5 | <0.4 |
| LEAD | 0.8 | <0.4 |
| MANGANESE | <1.7 | <0.2 |
| MERCURY | 3 | 2 |
| MOLYBDENUM | <5.8 | 52 |
| NICKEL | 10 | 5 |
| SELENIUM | 0.6 | <0.2 |
| SILVER | 0.5 | <0.4 |
| THALLIUM | 0.5 | <0.4 |
| VANADIUM | 14 | <2 |
| ZINC | 5 | <2 |

## FIGURE 15
## TRACE ORGANICS IN FUEL GAS

| STREAM NO. | (7) EASTERN COAL | (7) WESTERN COAL |
|---|---|---|
| **COMPONENT μg/SCM** | | |
| BENZENE | 139 | 210 |
| ALKYL BENZENES | 16 | 54 |
| NAPHTHALENE | 2 | 15 |
| ANTHRACENE | 0.2 | 0.12 |
| FLUORANTHENE | 1.1 | – |
| INDENE | – | 3.2 |
| PYRENE | 0.3 | – |

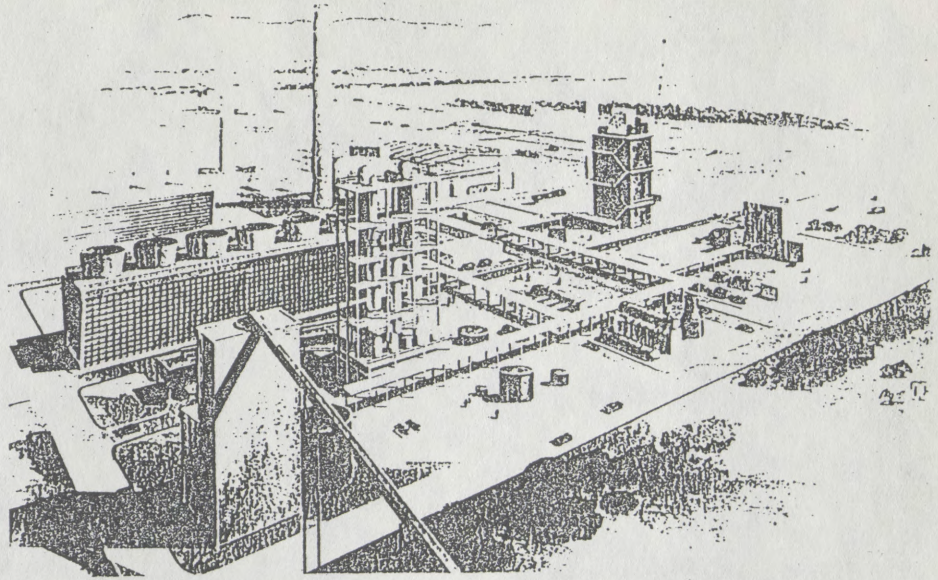

FIGURE 16

**Conceptional Design of the Texaco/SCE**
**Coal Gasification Combined Cycle Power Plant**

# SUPPLEMENTAL TESTIMONY

FROM

UNITED PARCEL SERVICE

ON A

STRATIFIED CHARGE ENGINE

United Parcel Service submits this statement in response to a request by the Subcommittee on Energy and Power for amplification of issues raised during testimony before the subcommittee on Dec. 18, 1980.

The transportation fuel problem has four facets that must, in our view, be considered monolithically: Fuel efficiency of the vehicle, crude oil conversion efficiency, emission standards and the pending synthetic fuels program.

The energy shortage has made it mandatory that these facets be considered parts of a single problem to be solved. To do otherwise would be wasteful of energy resources, as can be demonstrated from recent history.

Traditionally, manufacturers have produced automotive engines and the petroleum industry has then supplied fuel to match the requirements of those engines.

Because there has been little coordination between engine design and fuel conservation goals, refineries have been forced to produce exotic fuels, like unleaded gasoline, which consume excessive quantities of crude oil in the refining process.

Engines requiring unleaded gasoline were a product of still another facet of this problem: Environmental considerations. Federal standards for exhaust emissions led to the catalytic converter, which led to unleaded fuel, which led to waste of crude oil in the refining process.

Engine design, fuel production and emission standards are so interlocked that a decision about one element will have tremendous impact on the other two. True fuel efficiency cannot be achieved until permanent and realistic standards are set for emissions. When this occurs, the innovative genius of American engineers can be loosed to produce engines and fuels that will fulfill the need for conservation as well as appropriate levels of clean air.

The automotive industry is forever waiting for still another environmental shoe to drop. At present, engine manufacturers do not know what some of the emission standards will be for the 1985 model year. It is unrealistic to expect manufacturers to invest in engine design work that may be rendered worthless by sudden imposition of a new emission standard. If public health evidence supports a certain emission standard, then that standard must be imposed on a permanent basis. This will permit everyone to work on propulsion systems against established norms.

The government is planning to spend tens of billions of dollars to produce synthetic fuels. But what characteristics shall these fuels have? Before those billions are spent on synfuels, it would be logical to determine what the fuel requirements will be for the engines burning this fuel. Compatability between fuels and engines must be defined in advance of further research to get the most out of our energy resources.

Engine design must be attempted that will maximize the use of whatever automotive fuel resources are available. Certainly a multifuel engine is highly desirable in the light of this nation's dependence on foreign oil, and the undefined nature of fuels that will be produced synthetically.

The UPS 292 SC engine conversion program is one approach to engine technology that warrants examination. We believe its broad application for all automotive uses would resolve many of the issues raised in this statement.

The project involves conversion of a 292-cubic-inch engine common in the UPS delivery fleet, by the addition of a fuel injection system and other components. The conversion produces excellent fuel economy and permits the engine to operate on many different fuels.

During the development of this project we learned that an exemption from the tampering rules of the Clean Air Act was required from the Environmental Protection Agency (EPA). We applied for and received an exemption for 10 engines. The exemption is for two years after which we must destroy the engines or return them to their original state.

One engine is operating in a UPS delivery vehicle. Two engines are undergoing laboratory testing and the other seven are being built. The results so far on fuel economy and tailpipe emission testing far exceed our expectations.

When we have developed a little more on-the-road, hard data, we intend to apply to the EPA to eliminate the two-year limitation, and also to permit construction of 500 or more engines without the requirement to destroy or rebuild after any period of time.

We believe the data we submit will convince EPA that this conversion is a viable solution to fuel economy, and actually produces an engine cleaner than it was prior to conversion. We then hope to convince them that we should be allowed to convert our fleet to this system.

Tailpipe emission tests of the type required in several states were made on the first prototype UPS engine. The engine was not fine-tuned or fitted with any emission devices. However, these tests show the engine would pass all existing state emission standards by a wide margin.

Attached is Appendix A which shows the emission levels of conventional engines in the UPS fleet which could be retrofitted. These vehicles were randomly tested in a cooperative program with the State of New Jersey when that state was setting up its emission standards. Test results show that in all cases the unmodified engines produced much higher levels of emissions than were generated by the first prototype of the UPS 292 SC.

Engine manufacturers have constructed multimillion-dollar emission testing laboratories to identify emission characteristics of engines. Under current regulations such equipment is required to legalize engines so they conform to federal standards set in terms of grams per mile or grams per brake horsepower hour. Such a requirement effectively bars attempts at innovation by an organization that does not operate such costly emission test laboratories.

United Parcel Service recommends that the regulations be redrawn to permit the legalization or certification of any engine if it can be shown that it passes state tailpipe emission tests. These state tailpipe emission test programs have been established to maintain acceptable levels of engine emission performance during the life of the vehicle. They thereby set the minimum standard such engines must meet to continue in service. This is a reasonable and cost effective approach to clean air.

Many benefits would accrue to the public if the UPS 292 SC is permitted to power the United Parcel Service package delivery fleet.

During a time of fuel shortage or imbalance between the various automotive fuels, the UPS engine could switch to that fuel which is in most plentiful supply and maintain delivery service essential to national commerce.

In addition, since the UPS 292 SC has a broad fuel tolerance, the UPS fleet could operate on fuels that the rest of the nation's road vehicles cannot utilize. For instance, the engine could function quite well on "pipeline interface," the mixture of various fuels that is generated in pipeline operations when different fuels follow one another through the pipeline and intermix. Also, some refineries have supplies of raffinates and cutter stock, which are byproducts of the refining process that are in excess of product needed for blending of fuels required by conventional engines. This, too, can be burned in the UPS 292 SC.

The ability of UPS to use such nonautomotive fuels in its fleet will increase the amount of fuel available to those who do not have multifuel engines in their vehicles.

The UPS 292 SC also offers energy advantages that are less obvious but just as important. Fuels such as alcohol and diesel oil present cold-starting problems. This new engine will start immediately in cold weather, irregardless of the fuel it is given.

The engine can be produced by conventional manufacturing processes. It does not require any exotic metals or untested technology. It is ready to go with components already available to manufacturers.

United Parcel Service believes it is particularly desirable to permit the test of the engine in a fleet environment where recordkeeping and maintenance are closely controlled. From such a test the maximum of useful knowledge can be obtained for the benefit of all manufacturers and designers of power plants.

United Parcel Service believes that this engine technology represents the most efficient approach to the national automotive fuel problem. It is a demonstrated technology that has relatively few unknowns. We know what kinds of fuel it will burn, we know it has high fuel efficiency, we know that it is a clean engine, witness the fact that an untuned prototype easily passed state tailpipe emission tests, and we know that it can be produced economically.

The genius of American enterprise can solve the national automotive fuel problem if the government will create an environment where rational engineering choices can be made. The petroleum industry knows how to get the most transportation fuel out of a barrel of crude oil, automotive engineers know how to build engines that will run on refinery-efficient fuels and meet reasonable requirements for clean air.

A unified approach to the energy problem cannot occur, however, when fuel production, clean air and engine design requirements are compartmentalized by government.

If the way is cleared for retrofitting of the UPS fleet with this innovative engine, it will provide a clear test of the benefits that can be derived from coordination of engine design, clean air objectives and refinery efficiency.

And finally, we were asked to supply information about the cost effectiveness of operating electric vehicles in a package delivery service.

The electric vehicle, at its present state of development, is much more costly to operate than a gasoline-powered vehicle of the same size.

Limited storage capacity in batteries restricts the use of such vehicles to high-density delivery areas where relatively few road miles are required. We do not believe such a vehicle will be a viable alternative to the internal combustion engine until considerable advances are made in battery storage capacity and weight. At present the weight of vehicle batteries equals the payload that the vehicle can carry.

It also has been indicated by research that there is a net loss in energy through use of electric vehicles. Energy consumed to generate electricity, plus the electrical loss stemming from the battery charging process, tends to produce the loss. Less energy would be used to perform a given amount of work by simply using a gasoline vehicle.

APPENDIX A

NEW JERSEY DEPARTMENT NVIRONMENTAL PROTECTION
BUREAU OF AIR LUTION CONTROL
MOBILE SOURCE CONTROL SECTION

Heavy-Duty Gas Truck Exhaust Emissions
United Parcel Service Fleet, Edison, Parsippany, and Secaucus, New Jersey

May 23-27, 1977

| Sample Definition | Sample Size | Idle HC Mean (ppm) | Idle CO Mean (%) | Cruise CO Mean (%) | FAILURES [Rate (%)] Idle HC | Idle CO | Cruise CO | Idle CO & Cruise CO | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Make: | | | | | | | | | |
| Chevrolet | 19 | 579 | 3.99 | 3.88 | 5(26.3) | 5(26.3) | 11(57.9) | 5(26.3) | 12(63.2) |
| Ford | 279 | 346 | 4.03 | 1.43 | 61(21.9) | 107(38.4) | 60(21.5) | 34(12.2) | 155(55.6) |
| GMC | 32 | 344 | 0.87 | 0.45 | 11(34.4) | 3(9.4) | 2(6.3) | 0(0.0) | 13(40.6) |
| International | 4 | 527 | 3.59 | 5.18 | 1(25.0) | 0(0.0) | 4(100.0) | 0(0.0) | 4(100.0) |
| Control Group: | | | | | | | | | |
| Pre-1971 | 87 | 406 | 4.94 | 3.01 | 11(12.6) | 17(19.5) | 37(42.5) | 13(14.9) | 43(49.4) |
| 1971 & Later | 247 | 346 | 3.29 | 0.99 | 67(27.1) | 98(39.7) | 40(16.2) | 26(10.5) | 141(57.1) |
| Vehicle Weight: | | | | | | | | | |
| 8000 lbs. | 31 | 461 | 3.02 | 3.09 | 6(19.4) | 4(12.9) | 15(48.4) | 4(12.9) | 16(51.6) |
| 13,000 lbs. | 14 | 412 | 4.53 | 2.22 | 2(14.3) | 0(0.0) | 3(21.4) | 0(0.0) | 4(28.6) |
| 16,000 lbs. | 270 | 336 | 3.73 | 1.26 | 63(23.3) | 102(37.8) | 51(18.9) | 32(11.9) | 147(54.4) |
| 19,000 lbs. | 1 | 240 | 5.80 | 4.60 | 0(0.0) | 0(0.0) | 1(100.0) | 0(0.0) | 1(100.0) |
| 27000 lbs. | 18 | 539 | 3.95 | 1.95 | 7(38.9) | 9(50.0) | 7(38.9) | 3(16.7) | 16(88.9) |
| Odometer: | | | | | | | | | |
| <50,000 miles | 227 | 332 | 3.09 | 1.06 | 55(24.2) | 73(32.2) | 36(15.9) | 16(7.0) | 120(52.9) |
| 50,000-100,000 | 99 | 414 | 5.16 | 2.36 | 21(21.2) | 40(40.4) | 36(36.4) | 21(21.2) | 58(58.6) |
| >100,000 | 8 | 557 | 3.72 | 4.01 | 2(25.0) | 2(25.0) | 5(62.5) | 2(25.0) | 6(75.0) |

NEW JERSEY DEPARTMENT [illegible] ENVIRONMENTAL PROTECTION
BUREAU OF AI[illegible] [illegible]LUTION CONTROL
MOBILE SOURCE CONTROL SECTION

Heavy-Duty Gas Truck Exhaust Emissions
United Parcel Service Fleet, Edison, Parsippany, and Secaucus, New Jersey

May 23-27, 1977

| Sample Definition | Sample Size | Idle HC Mean (ppm) | Idle CO Mean (%) | Cruise CO Mean (%) | FAILURES [Rate (%)] Idle HC | Idle CO | Cruise CO | Idle CO & Cruise CO | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Engine Size: | | | | | | | | | |
| 152CID | 1 | 450 | 2.50 | 4.50 | 0(0.0) | 0(0.0) | 1(100.0) | 0(0.0) | 1(100.0) |
| 190CID | 1 | 360 | 3.80 | 4.20 | 0(0.0) | 0(0.0) | 1(100.0) | 0(0.0) | 1(100.0) |
| 220CID | 3 | 184 | 1.34 | 1.82 | 1(33.3) | 0(0.0) | 3(100.0) | 0(0.0) | 3(100.0) |
| 250CID | 19 | 579 | 3.99 | 3.88 | 5(26.3) | 5(26.3) | 11(57.9) | 5(26.3) | 12(63.2) |
| 262CID | 2 | 925 | 5.85 | 4.68 | 2(100.0) | 0(0.0) | 2(100.0) | 0(0.0) | 2(100.0) |
| 292CID | 31 | 350 | 0.81 | 0.43 | 11(35.5) | 3(9.7) | 2(6.5) | 0(0.0) | 13(41.9) |
| 300CID | 260 | 330 | 4.01 | 1.35 | 53(20.4) | 98(37.7) | 50(19.2) | 31(11.9) | 137(52.7) |
| 302CID | 1 | 300 | 7.80 | 1.60 | 0(0.0) | 1(100.0) | 0(0.0) | 0(0.0) | 1(100.0) |
| 361CID | 10 | 551 | 3.54 | 2.40 | 4(40.0) | 5(50.0) | 6(60.0) | 3(30.0) | 9(90.0) |
| 391CID | 6 | 483 | 4.18 | 1.39 | 2(33.3) | 3(50.0) | 1(16.7) | 0(0.0) | 5(83.3) |

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF AIR POLLUTION CONTROL
MOBILE SOURCE CONTROL SECTION

Heavy-Duty Gas Truck Exhaust Emissions

United Parcel Service        Edison, Parsippany, and Secaucus, New Jersey

May 23-27, 1977

| Sample Definition | Sample Size | Idle HC Mean (ppm) | Idle CO Mean (%) | Cruise CO Mean (%) | FAILURES [RATE(%)] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Idle HC | Idle CO | Cruise CO | Idle CO & Cruise CO | Total |
| Model Year: | | | | | | | | | |
| 1977 | 6 | 230 | 2.06 | 0.17 | 1(16.7) | 0(0.0) | 0(0.0) | 0(0.0) | 1(16.7) |
| 1976 | 91 | 327 | 1.57 | 0.40 | 25(27.5) | 11(12.1) | 5(5.5) | 2(2.2) | 31(34.1) |
| 1975 | 7 | 251 | 5.34 | 0.81 | 1(14.3) | 5(71.4) | 1(14.3) | 1(14.3) | 5(71.4) |
| 1974 | 28 | 319 | 3.95 | 0.72 | 7(25.0) | 13(46.4) | 3(10.7) | 1(3.6) | 17(60.7) |
| 1973 | 53 | 394 | 4.10 | 1.22 | 16(30.2) | 31(58.5) | 9(17.0) | 5(9.4) | 41(77.4) |
| 1972 | 24 | 474 | 4.65 | 2.13 | 9(37.5) | 16(66.7) | 9(37.5) | 8(33.3) | 19(79.2) |
| 1971 | 38 | 299 | 4.71 | 1.71 | 8(21.1) | 22(57.9) | 13(34.2) | 9(23.7) | 27(71.1) |
| 1970 | 25 | 274 | 4.94 | 2.03 | 0(0.0) | 3(12.0) | 5(20.0) | 2(8.0) | 6(24.0) |
| 1969 | 11 | 348 | 7.56 | 4.65 | 2(18.2) | 6(54.5) | 8(72.7) | 4(36.4) | 10(90.9) |
| 1968 | 3 | 327 | 5.79 | 5.12 | 0(0.0) | 1(33.3) | 2(66.7) | 1(33.3) | 2(66.7) |
| Pre-1968 | 48 | 493 | 4.29 | 3.01 | 9(18.8) | 7(14.6) | 22(45.8) | 6(12.5) | 25(52.1) |
| TOTAL | 334 | 362 | 3.72 | 1.52 | 78(23.4) | 115(34.4) | 77(23.1) | 39(11.7) | 184(55.1) |

BANK OF AMERICA

MERLE FISHER
Vice President

January 6, 1981

Mr. John D. Dingell
Chairman
Congress of the United States
House of Representatives
Washington, D.C. 20515

Dear Mr. Dingell:

At the recent hearing on Alternative Fuels and Engines, you asked those of us who testified to give additional thought regarding recommendations that will expedite the nation's conversion to alcohol fuels. I believe that economic incentives intelligently designed and implemented will achieve the conversion goal much faster than legislative regulation. Experience has taught us, that legislative regulation only increases cost and hinders the private sector in its attempt to make progress.

The development and marketing of engines specifically designed to burn alcohol (Ethanol or Methanol) in concert with an adequate alcohol fuel distribution system is vital to rapid development. The conversion of gasoline engines to the use of alcohol is merely a first step in the technology, however, it is an important first step. In my opinion, the automotive industry can contribute in a very positive way. It is clear and understandable that the large auto makers, for economic reasons, are not interested in the production of alcohol cars at this time because there is not a national alcohol fuel distribution system in place. The auto makers can however assist the smaller manufacturers who are taking the initial risks and developing the first visable markets by requiring their parts makers and suppliers to use materials that are compatible with alcohol.

The inconsistency of materials used in mass produced engines is unbelievable. For example, they may have several companies engaged in the process of making engine gasketing materials and carburetor parts. The general design of these parts is very specific but a wide range of materials and metals are used some of which are not compatible with alcohol. Materials and metals compatible with alcohol are certainly available.

The cost and time involved in converting gasoline engines to alcohol can be reduced substantially be using metals and materials that are compatible.

Sincerely,

Merle Fisher

Mr. OTTINGER. Our next panel consists of social and environmental consequences, advantages, disadvantages, of going to methanol. It will consist of John McCormick, the Washington representative of the Environmental Policy Center; Mr. Daniel Luria, energy analyst for the United Auto Workers; and Mr. Sam M. Church, Jr., of the United Mineworkers of America.

Gentlemen, if you would come up at this point.

I would like to move as rapidly as we can. Let us start with Mr. McCormick. Mr. McCormick, your statement will appear in full in the record. We would welcome it if you could summarize it.

## STATEMENTS OF JOHN L. McCORMICK, WASHINGTON REPRESENTATIVE, ENVIRONMENTAL POLICY CENTER; DANIEL D. LURIA, ENERGY POLICY ANALYST, UNITED AUTO WORKERS; AND MICHEAL BUCKNER, RESEARCH MANAGER, UNITED MINE WORKERS OF AMERICA

Mr. McCORMICK. Thank you, Mr. Chairman. It is a pleasure to be here this morning to discuss an issue which we think is of vital importance to the Nation. This committee is to be complimented on first of all holding this hearing after a very difficult last several weeks in the lameduck session. I think your diligence in wanting to pursue this issue is very commendable.

Mr. Chairman, I have a fairly lengthy statement I will not read, and will try to provide some extemporaneous remarks for the record. [See p. 158.]

At the outset, Mr. Chairman, let me say that the Environmental Policy Center, as well as many environmental organizations, have taken a critical view of the Federal Government's role in commercializing synthetic fuels. We feel that some of the technologies that have been advanced beyond the research and development phase and into the commercialization phase ought best be left to the private sector and not to the taxpayer. Projects such as the SRC-2 coal liquefaction project in West Virginia in our estimation is money poorly spent, because the end product, clean boiler fuel, is a very expensive product, and there are much more cost-effective means of using coal for electric generation without violating the Clean Air Act.

To give you one example, fluidized bed coal combustion would be a far more practical direction to go in our use of medium- and high-sulfur coals for electric generation rather than going through the very expensive, complicated, and financially risky SRC-2 project. To get down to the specifics of this hearing, the policy center is very encouraged by the testimony that we have heard this morning from Bank of America and the United Parcel Service, where those companies have taken it upon themselves to do what our Federal Government does not seem to be doing very well. That is taking existing technology, technology that has been around since 1936, perfecting—excuse me—perfecting automobile engines to burn a fuel that can be derived from those technologies. We see the potential for the use of northern Appalachian, southern Ohio, and southern Illinois medium- and high-sulfur coals being used as feedstocks in medium- and low-Btu coal gasifiers, and again technologies that are practically off-the-shelf items and taking that low- and medium-Btu gas and running it through a methanol synthesis process, once again a technology that is state-of-the-art, and arriving at a methanol fuel which has superior characteristics over that of gasoline, and using that as a fuel for captive fleets such as Bank of America is a far more environmentally acceptable and cost-benefit-ratiowise idea than, again, the synthetic fuels corporations ideas and the direction that they would take us.

We see the effluents from low- and medium-Btu gasifiers as being acceptable under the Clean Air Act. We also see the potential for low- and medium-Btu gasifiers combined with a methanol synthesis product as being batch-plant oriented: decentralized, small plants located in and around the high-sulfur coal fields of Appalachia and providing a readily marketable fuel for Government fleets, State and local government fleets, as well as the private industry's captive fleets.

Upon that, Mr. Chairman, I would like to end my comments and be available for questions. Thank you.

[Testimony resumes on p. 168.]

[Mr. McCormick's prepared statement follows:]

74-152 O - 81 -- 11

ENVIRONMENTAL POLICY CENTER
317 Pennsylvania Ave., S.E., Washington, D.C. 20003
202/547-5330

TESTIMONY OF JOHN L. McCORMICK DECEMBER 18, 1980

BEFORE THE HOUSE INTERSTATE AND FOREIGN COMMERCE COMMITTEE'S

SUBCOMMITTEE ON ENERGY AND POWER

ALTERNATIVE FUELS AND ENGINES HEARING

= = = = = = = = = = = = = = = = = = = =

Mr. Chairman and Members of the Subcommittee,

It is a pleasure to appear before you this morning to participate in one of the more important hearings of this Congress. The Environmental Policy Center has been involved in the debate on the issues of synthetic fuels development since the first session of the 94th Congress. It was during that time when this Committee participated in a successful effort to persuade the House to reject a Senate-sponsored $6 billion guaranteed loan program for synfuels commercialization. Since then, the Congress has devoted far too much time--and, now, $20 billion in Federal subsidies--to this quick-fix non-solution to our liquid fuels shortage. However, this Committee has continued to show good judgement and a reasoned view of the role that synthetic fuels might play in the future and this hearing is exemplary of that position.

The impetus for domestic development and large-scale commercialization of synthetic fuels processes stems from two basic needs. Primarily, this Nation sees synthetic fuels as a means to reduce oil imports, thereby becoming more energy self-sufficient while we make use of our abundant energy resources. Secondarily, synthetic fuels represent technologically feasible substitutes for rapidly diminishing crude oil and natural gas resources. While those may be appropriate concerns for Americans to address, they are not the only criteria upon which to base decisions to commit billions of dollars in capital and subsidies to such technologies. Of greater importance is the nature of the synfuels product and the end-use to which it will be dedicated; the resource demands and social/economic/environmental impacts of a particular process; and, the anticipated cost of the synfuel product. When all of these factors are taken into account, most of the highly touted synthetic fuels processes already funded and under consideration for funding, prove to be poor choices.

Some examples of the failure of the Department of Energy, and now the Synthetic Fuels Corporation, to weigh all of the factors instead of settling upon the politically expedient choices would include the following:

a. The SRC II process, being constructed in West Virginia, primarily at tax payer expense, produces a clean, sulfur- and ash-free boiler fuel from coal. While that product may have its environmental advantages, boiler fuel is not exactly a commodity in short supply as any Midwestern oil refiner will be quick to point out. Furthermore, the high capital cost and operating expenses of the plant and the \$4.50-\$5/mmbtu cost of the product is significantly higher than atmospheric fluidized-bed coal combustion costs.

b. The Great Plains Gasification Project, proposed for construction in North Dakota, has suffered yet another economic setback since a U.S. Court of Appeals overturned a F.E.R.C decision allowing the project sponsors to add a surcharge to customers' bills to assist in the capitalization of the high-btu coal gasification plant. The sponsors have been unable to convince the financial interests that the synthetic natural gas would find a receptive market regardless of its \$8-9/mcf price. Given the new discoveries of unconventional natural gas and the sharp increase in exploration for conventional gas, SNG may be the most expensive gas on the market for the next twenty years. Coal gasification's dependence upon subsidization will continue to increase as more natural gas deposits are developed.

c. Oil shale development, whether surface retort or in-situ processes are used, represents the most resource-intensive synfuel technology. The low-yield ore, with its poor carbon-to-hydrogen ratio, and its demand for 3 barrels of water per barrel of product, make oil shale particularly unsuitable. In addition, its end-use as a substitute for gasoline is not attractive given the high production cost of of the shale oil. Again, it is a process dependent upon financial subsidies which develops an expensive product for which there are less expensive substitutes.

d. The Fisher-Tropsch, indirect coal liquefaction technology is being used extensively in South Africa to convert indigenous coal resources to synthetic crude oil and to gasoline. Its high capital costs are acceptable in light of South Africa's almost total dependence upon the Middle East for oil imports. The technology is water consumptive and it emits small amounts of known and suspected carcinogens in waste gases. The technology is being investigated by U.S. corporations for use in this country to produce gasoline from coal despite its high costs, environmental risks and less expensive alternatives.

e. Gasahol, a mixture of one part ethanol and nine parts unleaded gasoline, has received wide political and economic support in the U.S. over the past four years. It is a transportation fuel substitute dependent upon enormous subsidies which range as high as $40/barrel. Its overall contribution to the U.S. transportation fuel mix is clouded by uncertainties such as unstable supply and price for feedstocks, its possible negative impacts upon future food prices, limited benefits in terms of air pollution reductions, and its continued reliance upon O.P.E.C.-influenced gasoline prices and supplies. Gasohol could not compete with methanol from coal were it not for the generous financial boost from U.S. taxpayers. Indeed, it is one of the most expensive synthetic fuels options being considered as a substitute for gasoline yet, it has enjoyed the strongest political support.

Upon close examination of this Nation's sporadic and circuitous ventures into programs designed to create a commercial synthetic fuels industry, it is fair to ask whether or not we agree upon where we are trying to go. Judging from the results over the past 35 years, one might conclude that we have been charting the course by committee, with some wanting to cover the greatest distance in the shortest time and others being more interested in sailing first class regardless of the final destination. But, we no longer can afford the luxury of heading off in one direction to see how far we can go. The political events which affect the price and supply of our most critical energy fuels are playing havoc with the economies of the free world and time is running out. We, as a Nation, must put aside all of the political rhetoric and stop playing up to private interests and come to grips with our passion for synthetic fuels.

We might begin by resolving several fundamental questions which come to mind:

1. Do we seek to replace imported oil with synthetic liquids and gases from domestic coal and oil shale, or will the synthetics supplement continued imports?
   If the synthetic products are actually intended to add to our fuels supply, then we had better prepare for continuously higher world oil prices since synfuels prices represent a floor price, not a ceiling price. We will be telling OPEC that our appetite for liquids is so ravenous, we are willing to sell ourselves domestically-produced $50-60/barrel syncrude in order to keep supplies up.

2. Do we want to use a synfuels strategy to exert downward pressure on world oil prices?
   It is possible for the U.S. to accomplish that goal to some degree but it will not come about by our promotion of oil shale and coal liquefaction as the answer. OPEC is well aware that we cannot gear up fast enough, nor can we assemble sufficient capital, to produce a significant enough amount of synfuels liquids in the next 20 years to have any affect on world oil prices. Synfuels is definitely a long-term strategy by anyone's estimate and OPEC will not be impressed with our short-term efforts, regardless of our financial commitment.

3. If we are serious about letting market forces determine our level of energy consumption, are we willing to kick synfuels technologies out of the nest to survive on their own?
The Energy Study Group of M.I.T. has been cautioning against Federal subsidization of synfuels but few policy-makers have listened. One MIT report offers this succinct view; "A commercialization program forces consumers to pay a good portion of the high cost of energy indirectly, through their taxes. As a result, there is little incentive to conserve, and consumption will grow as production falls. A growing tax burden will then be required to finance a growing share of subsidized production."
Federal subsidization, particularly guaranteed loans, will eventually have a market effect similar to that of price controls. The synfuel product will be priced artificially low (below replacement costs), since the plant's capital cost will be reduced, thereby allowing the higher cost product to compete in the marketplace. The consumer will not be paying the real cost for the fuel and will not have as great an incentive to conserve its use.

4. How do we benefit from a commercial synthetic fuels industry founded upon increased government spending and production costs in excess of world oil prices?
Synfuels proponents argue that private capital will not flow towards the various synthetic fuels projects until there is certainty within the investment community that the risks are manageable. They propose that the taxpayer will ultimately benefit from synfuels production so the Federal Treasury should underwrite those risks. However, that assumes that economically unsound energy projects will evolve into profit-making ventures after the Federal government allows second-generation technologies to proceed unaided. There does not appear to be any hard evidence that future synfuels technologies will be less expensive and more competitive with world oil prices. In fact, the reverse has been demonstrated over again as estimates of oil shale costs have continued to outdistance world oil prices.

5. Should the consumer/taxpayer be asked to cover all bets by subsidizing any and all potentially promising synfuels technologies?
The Congress, in the past, has been willing to invest tax dollars in the research and development or the financial subsidization of a variety of oil shale, coal gasification and liquefaction, coal solids fuels, biomass processes and any other synthetic fuels process fortunate enough to find a sponsor in the executive or legislative branch. Now that function has been delegated to the Synthetic Fuels Corporation.
The energy industry has continued to preach the view that we should try each of those technologies because the future will require a great insurgence of synthetic fuels products as scarce oil and natural gas resources play out. While we have the lead time, we should experiment with all potential technologies and let the private investors choose which processes to develop commercially. Here is where politics takes command and cost/benefit considerations are put aside for the sake of "National Security". If we continue to follow that policy, we can assure ourselves more "red ink" and increased oil imports.

With the change of Administrations, and the approach of a new Congress, there is an opportunity to completely evaluate our commitment to synthetic fuels. It will require an objective appraisal of what we hope to accomplish with more research while we move forward with technologies we are confident will work and produce fuels we can afford. Clearly, there have been successful technologies, particularly in the area of low and medium btu coal gasification. Banking on those well-known processes, we should be able to construct a synfuels industry which matches an abundant resource --high sulfur coal -- with an eager market - transportation fuels. By matching two relatively simple, state-of-the-art technologies, we can convert that coal into methanol to supply several needs simultaneously, without plant modifications and at costs far below those estimated for other coal liquefaction processes.

Coal has been converted to a synthetic gas, called synthesis gas, since the early 1930's. The Geraman army developed the Lurgi coal gasification process, a forerunner of present-day technologies, to produce petroleum fuels for its war machine. Since then, the U.S. has devoted much time and money to adapt that technology to the types of coal found in this country. By partially combusting the coal using high temperature and pressure, gases are emitted, trapped and cleaned of impurities. The eventual product is synthetic gas which is essentially methane ( $CH_4$ ). Variations on this basic process can yield different products depending upon changes in the feedstock. For example, combustion of the coal in the presence of air will produce a gas with a low btu content, in the range of 100 to 300 btu per cubic foot, versus methane which has about 990 btu. Substituting oxygen in place of air in the gasifier will produce a richer synthesis gas with a 300-600 btu per cubic foot content.

The synthetic gas output will make an ideal boiler fuel for industrial boilers; it could serve as a petrochemical feedstock: or, as a feedstock for a methanol synthesis reaction. The design and operation of methanol synthesis plants is a well understood technology and the U.S. already has a significant production capacity on line. There are virtually no technical risks involved and there does not appear to be any difficulty in siting and permitting such facilities.

Once the methanol has been processed, the liquid fuel is available for a host of end uses. It can enter the petrochemical markets as a substitute for feedstock alcohols presently being produced from petroleum and natural gas. This may be the earliest and easiest market in which methanol can compete. Current U.S. market demand for chemical grade methanol is about 50,000 barrels per day. Therefore, initial entry into the petrochemical market may be slow but the potential for expansion will be a function of the market price for natural gas after controls are lifted entirely. It should be pointed out that remote deposits of natural gas, such as found in the Arctic Islands, may be convered to methanol to facilitate shipment over great distances. Gulf Oil Co. is investigating such a venture in Northern Canada for eventual sale to Eastern U.S. markets.

Utility markets, particularly in California where stringent air quality laws are being enforced, may also offer a lucrative transition market for coal-based methanol. For both peak shaving of electric power demand in single-cycle gas turbines, as well as combined cycle generators, and possibly in limited intermediate base-load generation plants, methanol may be an ideal and inexpensive fuel. The space heating and industrial boiler markets may find uses for methanol particularly where intermittant use of the boilers might require storing the fuel on site. Since low and medium btu synthetic gas cannot be transported economically over great distances, conversion of the gas to methanol would overcome that limitation.

The largest potential for methanol, however, will likely occur in the transportation fuels markets. Here, methanol's key role in transportation as a replacement for oil products is for use in automobiles and gasoline-fired light duty trucks and vans. Current research and development work with heavy-duty trucks, and even prop aircraft, may offer additional markets.

As a transportation fuel, methanol could be used as a chemical additive to enhance octane requirements in unleaded gasoline. While this market may be limited in size, it does offer the opportunity for immediate sales. Though it can be blended with gasoline, it does not blend as easily as ethanol and blends of about 5% appear to be optimal. Therfore, this will be a limited market for methanol.

The most significant contribution of methanol to any market will be its use as a "neat" fuel where it is used directly in internal combustion engines. The preceding panel offered sufficient testimony on the technical and economic aspects of engine design, operation experience and maintenance costs and this paper will not try to amplify their views. Instead, I would like to focus on a discussion of the role this government might play in encouraging capital into the coal-based methanol field.

In 1978, the Federal government consumed about 124 million gallons of gasoline and diesel fuel in its non-military automobiles, trucks and buses. Military demands for those fuels brought the total fuels purchase to about 222 million gallons. For comparision, state and local government automobiles, trucks and buses consumed about 1.8 billion gallons of fuel during that same year. While these totals do not represent even one percent of the 111 billion gallons of transportation fuels consumed in highway driving throughout the Nation during 1978, the Federal and State government's demand for fuels represents a significant market over which the taxpayer has some discretion.

If we focus our attention upon a single state, Ohio, for example, we can see the influence that govenment fuel demands could have on a methanol market. If the various Federal agencies operating motor pools in that State were to call for bids on the least expensive rolling stock and fuel to supply that agency's needs in the state, it is possible that a consortia of interests might submit a bid to produce engines with a high fuel efficiency, capable of burning methanol and supply the methanol as well.

To follow the example to its conclusion, let us assume that the United Mine Workers of America teamed up with the United Auto Workers to back such a proposal with capital from their pension funds. The UMWA could contract out for the design, construction and operation of a 45,000 to 50,000 barrel/day oil equivalent methanol plant which would convert Southern Ohio high sulfur coal to low btu gas for synthesis to methanol. Given the low risk technology and the secured Federal market for the fuel, the UMWA would be able to attract investment dollars for the project which could yield a product with an at-the-gate price of 44¢/gal. (or, less than 90¢/gal on a gasoline-btu equivalent basis).

By investing its own capital in such a project located in a coal producing region hit hard by unemployment due to a soft market for high sulfur coals, the Union would be generating investment and creating jobs where they are needed most. Furthermore, the Federal government would benefit from the economic, environmental and National security advantages that go with buying and burning domestically produced transportation fuels.

The United Auto Workers could, in a similar fashion, put up capital by transferring funds from its Pension Fund to finance the construction, or retrofit, of an assembly plant to manufacture vehicles equipped with engines designed to burn methanol. By incorporating the latest in fuel-efficient design, the vehicles could offer substantial fuel savings - therefore, diminish the operating costs borne by taxpayers. Compact passenger cars and postal delivery vans are presently fitted out with methanol-burning engines but their share of the U.S. auto fleet is infinitesimal. However, with the economic advantages of mass-production, such assembly plants would soon offer the commercial market an auto or van which could compete favorably with subcompact imported cars but, with an additional advantage,- these vehicles could be powered on American high sulfur coal.

This type of planning has not been a part of the Federal government's approach to expansion of the synfuels market. Nor, has such a plan been suggested by the Defense Department or any other government agency, despite the government's critical need to reduce Federal spending in order to check inflation. However, a similar plan has been conceived and implemented by the private sector and the representative from the Bank of America described it for you this morning.

If productivity must be increased in this Nation to help improve our economy, we must not overlook any potential available to us to cut costs and improve on efficiency. It makes a great deal of sense to begin with the Federal and State governments and their needs for transportation equipment and fuels is the best place to begin. There is one synthetic fuels technology we are certain will operate and produce a product that can be used in many beneficial ways. That technology is low-btu coal gasification. The public has been promised a good return on its synfuels investment. Methanol from coal is at the top of the list. We have to make it happen, and soon.

Mr. OTTINGER. Thank you very much.

Next we will hear from Dr. Daniel Luria.

## STATEMENT OF DANIEL D. LURIA

Mr. LURIA. We, too, appreciate the opportunity to present our views to the subcommittee today. What I want to talk about today are four things: first, methanol versus direct liquefaction of coal and shale; second, methanol as part of an indirect liquefaction fuel cycle; methanol as a transport fuel; and the role that refinery upgrading has to play in implementation of the cycle I am going to discuss.

I want to begin with an obvious point, that is that the health of the transportation sector with which we are vitally concerned is principally dependent on the steady availability of predictably affordable fuels. I want to stress those four words: steady, available, predictable, affordable. From that perspective we have a bias for fuels that are domestic in feedstock geography, drawn or produced from a large resource base, producible quickly and therefore with existing technology, and less expensive than all near-substitute liquid fuels.

Given the subject of these hearings, I am probably expected at this point to announce our strong preference for methanol over other synthetic liquids. Methanol is indeed our preferred synthetic liquid. But I really see my role today as being one of arguing for a fuel cycle and not just a fuel. That cycle, as several other people mentioned today, involves the gasification of a wide variety of coals into low- and medium-Btu synthetic gas, and if desired and needed the production from such synthetic gas of methanol.

In the rest of my statement I am going to refer to low- and medium-Btu gas as low-Btu gas, simply to speed things up a little. The beauty of this fuel cycle is that its first step alone—large-scale production of low-Btu gas from coal—can, if accompanied by appropriate policy, largely solve the transportation sector's fuel needs through approximately the year 2010.

Let me spell out how that could work. First, a system of political mandates, and if necessary of taxes, subsidies, and outright grants could be used to induce large industrial and electric utility petroleum and natural gas users to switch to coal, with the assurance that synthetic gas would be made available on a noninterruptible basis when air quality or scrubber maintenance problems ruled out direct coal burning.

Second, residential users would be induced to switch from heating oil to natural gas, the latter having been freed up by industrial and utility fuel switching away from natural gas.

Third, U.S. refineries would be upgraded to crack almost all of even sour crudes into light fuels suitable for transportation. Many of you may be aware that Ashland Oil, for example, is in the process of constructing refineries that can crack even relatively low-grade crudes into 65 percent gasoline, 10 percent diesel fuel, and 10 percent aviation fuel.

Mr. OTTINGER. May I interrupt you there a second? I would ask if you went to this Texaco kind of engine, then I take it you would not need to make significant and expensive changes in refineries? You would save a substantial amount of cost and a substantial amount of fuel and capital in running your additional refinery changes.

Mr. LURIA. I am going to get to that. At this point I am not even at the methanol stage. I am simply at the synthetic gas stage.

Significantly, the residual oil that would be produced by such upgraded refineries can be coked and gasified, further increasing industrial gas supplied beyond that available from coal gas. These three steps by the end of this century would mean that about 80, rather than today's 50, percent of U.S. oil use would be in the transportation sector. If you assume an on-road vehicle fleet of about 160 million units, up from about 120 million units today, averaging 26 miles per gallon, up from today's 16 miles per gallon, and adding about 800,000 barrels a day for aircraft fuel, by about the year 2000 the U.S. transportation sector could get by nicely on about 7½ million barrels a day of refined product. Based on the consensus forecast that U.S. crude production in the year 2000—sustainable through about the year 2020—will be about 7 million barrels a day, it follows that at 80 percent transport fuels per barrel, the sector's domestic shortfall is only about 1.9 million barrels per day of product, which would necessitate somewhere between 3 and 3.8 million barrels a day of methanol production or 2.4 million barrels a day of oil imports, or some mix of the two.

I realize this scenario is exceedingly optimistic. It assumes that there is a tremendous amount of fuel switching that will occur in a mere two decades. It assumes that new refineries will be built and existing ones radically altered, at a cost of perhaps $40 billion above "business as usual." It assumes finally that the resources needed to finance fuel switching and refinery upgrade will not flow instead into unnecessarily expensive, long leadtime shale and direct coal liquefaction projects.

Let me be a little less wildly optimistic and posit a year 2000 by which only half of the fuel switches and half the improvement in light product yield actually occur. In that view, our domestic 7 million barrels a day of crude production yields only 4.55 million barrels per day of transport fuels, producing a transport shortfall of about 3 million barrels per day. The total shortfall is something like 6 million barrels a day to be made up by imports or domestic synthetic liquids.

That scenario in my view probably requires significant domestic synthetic liquids production. I do not think we can count on 6 million barrels per day in the year 2000 in oil imports.

The synthetic liquid should be methanol, for six reasons.

First, as we heard today, methanol is an acceptable multipurpose engine fuel for use in everything from the peaking turbines that now use about 400,000 barrels per day of oil to car engines modified to use systems such as the TCCS system that was described earlier this morning.

You may be interested that the November/December 1980 Technology Review has a very useful summary of car engines, and they stress the multiple-fuel compatibility of the TCCS as very important.

Second, and probably more important, methanol is producible as part of this coal-to-syngas-to-methanol cycle that I have been talking about, where all other synthetic liquids are as it were ends in themselves. Methanol from indirect coal liquefaction is just one part of a cycle that uniquely solves many problems at once. Already that cycle is producing clean, low-Btu coal gas at less than $4 per million Btu's, which is cheaper than residential natural gas and cheaper than the refiner acquisition cost of domestic crude oil.

Third, methanol is affordable, and will continue to be so. The best cost numbers I have seen—or, as one should say in this field, the numbers I believe most—give methanol a substantial price edge over every other synthetic liquid.

Expressed in 1979 dollars per 128,000 Btu's and allowing for normal rates of return at all levels, methanol from indirect coal liquefaction comes in at $1.47, gasoline from coal-derived syncrude at $2.43, diesel fuel from shale oil at $2.10, and unsubsidized ethanol from sugar cane bagasse at $2.29. These figures should be compared with unleaded gasoline and diesel fuel from crude oil at $1.13 and 97 cents respectively.

Assuming conservatively that real crude prices rise 4 percent a year, with a one-time 5 percent jump in the last and biggest decontrol step next October, and that real methanol prices don't change, methanol would undersell the weighted gasoline-diesel fuel composite by 1987.

In fact, these figures greatly understate methanol's affordability. Because engines such as the TCCS can handle methanol at compression ratios of 13 or 14 to 1, fuel economy should be on the order of 20 percent better than today's 8.5-to-1 gasoline burning powerplants.

Mr. OTTINGER. While we are on these figures, before we forget them, the people of Bank of America say they are presently buying methanol at 92 cents a gallon.

Mr. LURIA. That is right. I am talking about per 128,000 Btu's, not per gallon.

Mr. OTTINGER. What does that translate into per gallon?

Mr. LURIA. Per gallon it probably translates into something on the order of 85 to 95 cents.

Mr. OTTINGER. That is cheaper than gasoline today.

Mr. LURIA. Per gallon. However, we don't have comparable heat content per unit of volume.

Mr. DINGELL. Would the gentleman yield?

I think something comes into play here. As I understand it, that is being made from natural gas as opposed to being made from coal. The cost of natural gas, as a feedstock, is much higher than the cost of coal as a feedstock. It is also lower in Btu's than coal is in Btu's per dollar.

There is an additional problem; that is, those are essentially small-scale pilot plants which don't produce a lot and which are not necessarily efficient. Your real cost of a well-run coal methanol plant would probably be somewhere—we have seen the figures in years past of as low as 35 to 40 cents a gallon, which probably now ought to be inflated to somewhere on the order of 50 to 60 cents a gallon.

Am I correct in those appreciations?

Mr. LURIA. I do think using coal as a feedstock rather than natural gas would no doubt reduce the cost.

Mr. DINGELL. Yes, and in a larger scale plant——

Mr. LURIA. I am unconvinced on that point. I think one of the advantages of methanol production relative to other synthetic liquids is that the scale factor is not that much lower. So, it may be that the methanol produced from coal using, for example, a 200 ton per day mine mouth medium Btu gasifer may in fact be roughly what we could expect.

There may be no particular advantage in going to a 50,000 or a 100,000 barrel per day methanol plant over say a 10,000 or 20,000 barrel per day plant.

Mr. DINGELL. That is coal versus coal as opposed to coal versus natural gas?

Mr. LURIA. That is right.

Mr. DINGELL. We must assume that the natural gas plant is something on the order of either roughly a pilot plant or a relatively primitive earlier stage development for the production. Am I correct?

Mr. LURIA. Correct. I guess I would say, therefore, that my figures are to be seen as sort of upper limits on what the cost of coal-derived methanol might be.

Mr. DINGELL. Mr. Chairman, I apologize. Could I make a couple of comments here at this point——

Mr. OTTINGER. You most certainly could.

Mr. DINGELL [continuing]. Which I think are important. We did a little bit of figuring based on some comments by the testimony from the Bank of America. They indicated that there is a potential for saving 15 percent of the gasoline used if we switch to methanol.

The cost of that imported at $40 a barrel would be about $13.3 billion a year. That is now going out of this country now in foreign exchange. If we kept that at home, we would save $13.3 billion, which is very important to this country because we are hemorrhaging and it is having both an inflationary impact on our economy and a deflationary effect on the value of the U.S. dollar. About a 900,000 barrel a day import saving in terms of that is being imported into this country.

Now, if we use methanol to displace that, it would require about 1.26 million barrels for the same amount of work. The cost in capital at about $10,000 per barrel on stream per day would mean about $12.6 billion. But that would save us in the first year $13.3 billion in foreign exchange which we are now witnessing going out of this country.

Now, I would say, Mr. Luria, based on your comments, Mr. McCormick's comments, and the comments of earlier witnesses, that every year we would save about 70 percent of the cost of the plant in foreign exchange over the life of the required investment.

In 10 years we would have—actually about 6 years—displaced in its entirety the oil being imported for the production of gasoline into this country and would have saved in the process the first year $13.3 billion, the second year $26.6 billion, and the third year $39.9 billion, out of an importation of oil and an exportation of dollars that is literally destroying the American economy.

I think we are going to have to get going on something in this area. I want to commend you gentlemen for your participation and assistance and just observe that during the forthcoming year Mr. Ottinger, my very dear friend and the valued chairman of this meeting today, and I are already talking about trying to get a cohesive energy and environmental policy that will enable us to move forward in this direction, so that we can stop this debilitating hemorrhaging of our natural and economic resources and the commitment of National policies with regard to automobile use that are extremely destructive, not only environmentally, but also of the economic well being of the country.

Mr. Chairman, I thank you for your courtesy.

Mr. OTTINGER. I couldn't agree more with the comments of the chairman.

Mr. Luria, have you finished your testimony?

Mr. LURIA. No, I have not. I was just going to go on to say because of the higher compression engines that would be compatible with methanol which are not compatible with unleaded gasoline, even my high end estimate makes methanol today, even made from natural gas, cheaper than gasoline.

Fourth, methanol from indirect coal liquefaction is the cleanest liquid to produce. According to DOE and Radian Corporation Data, atmospheric discharges of particulates, sulfur dioxide, nitrogen oxides, carbon monoxide and hydrocarbons from a 250 million cubic foot per day low Btu coal gas plant would be from 25 to 95 percent less than from an equally import-displacing 250 billion Btu per day coal liquefaction plant with associated crude refinery. Solid wastes would be 10 percent lower. Water requirements would be 60 percent lower.

Mr. OTTINGER. The water requirements are 60 percent——

Mr. LURIA. Water requirements.

Mr. OTTINGER [continuing]. Are 60 percent lower——

Mr. LURIA. Lower than they would be in processes that directly liquify coal or shale into synthetic liquids.

Fifth, methanol is relatively clean burning in high compression internal combustion engines. Tests in vehicles operated by the California Energy Commission exceeded 1983 emissions standards of 0.4 grams per mile of NOx and 4 grams per mile of CO.

Sixth, the coal-to-gas-to-methanol cycle works. Those of us who are paid to follow the synfuels field come across hints every once in a while that other cycles have serious problems that defy technical fixes.

Two recent examples: American Natural Resources' high Btu gasification complex is using at least two processes that, according to several ANR engineers, may simply not work; and shale- and coal-derived syncrudes may not be easily refinable into stable light products.

Some of the problems observed are increasing thickening, or viscosity, during the approximately 6 months that these synthetics often have to be stored, and second, especially for light distillate fractions gum formation which could clog fuel lines.

We have conveyed our feelings in this area to the appointees of the U.S. Synfuels Corporation. I have a copy of that letter to introduce into the record.

Mr. OTTINGER. Without objection.

Mr. LURIA. We are continuing to study developments in the alternative fuels field. I hope the work of this Subcommittee can put us on the least cost, cleanest, readiest synfuel cycle. That cycle is the transportation sector's best chance for the future. That concludes my remarks. Thank you very much.

Finally, I want you to know that, in our view, there is more to the synfuel debate than fuel choice. We are distressed by the widespread presumption that the Government should simply assume private industry's risk, without exerting any influence over the projects undertaken. We also see the massive future demand for energy-related hardware as an opportunity to reindustrialize hard-hit Midwestern cities, through targeted procurement and direct economic incentives.

Mr. Ottinger. Thank you very much.

[The letter referred to follows:]

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October 21, 1980

Dr. John C. Sawhill
Chairman of the Board
United States Synthetic Fuels Corporation
1200 New Hampshire Avenue, N.W.
Washington D.C. 20036

Dear Mr. Sawhill:

I am writing you in your capacity as a director of the new U.S. Synthetic Fuels Corporation to apprise you of the UAW's thinking on the appropriate emphasis for the nation's emerging synfuel program.

There is no convincing evidence that coal- or shale-based liquids can be refined into stable light fuels and sold profitably at under $100 per barrel. Current estimates of $40-65 per barrel are pre-refinement. In any case, the Congressional Research Service and others predict that, realistically, at most 200,000 barrels per day of synthetic liquids can be produced by 1990. We are extremely concerned that overestimates of synfuel production and underestimates of synthetic liquids' costs are responsible for OPEC's recent statements that U.S. synfuel liquids will from now on be considered to place the operative price ceiling on world-traded oil.

Of the synfuel projects now producing, only those converting coal to low- and medium-BTU "syngas" — and, in some cases, continuing on to methanol -- have any near-term potential to reduce U.S. petroleum demand from the supply side.

They are also producing energy at a price below the $6 per mmBTU cost of imported oil at the refinery gate. Syngas backs out both light and residual oils in industry, frees up high-BTU natural gas that can replace heating oil for residential/commercial uses, and provides a peaking and/or back-up fuel for electric utilities, as well as allowing utilities in low air quality areas to switch from oil or natural gas. Methanol catalysed from syngas can back out naphtha in petrochemicals, permitting better gasoline, diesel, and aviation fuel yields per barrel from all but the smallest U.S. refineries.

A liquids-oriented synthetic fuel program appears, for now, to be a dangerous waste. An effective synfuel program, in our view, emphasizes coal gas, methanol, and refinery upgrading. Switching stationary uses off of petroleum liquids and increasing light product yields per barrel is the best -- and, in the near term, the only -- way to hold down U.S. oil imports.

We attach some supporting materials.

In addition, we believe that the development of a synthetic fuel sector should be used as a major opportunity to launch a new U.S. industrial policy. Government subsidies, financed from windfall oil profits tax receipts, and federal procurement should favor those investments that create employment in cities and regions hardest hit by the sudden transition to a world of expensive hydrocarbon fuels. City and State governments should be treated as employers of last resort, to ensure that funds go where needed in cases where the private sector proposes no comparable project in the targeted locations.

We look forward to a continuing dialogue on these questions.

Sincerely,

Daniel Luria, PhD
Energy Analyst

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Attachments

cc: House Energy and Power Subcommittee
Senate Energy and Natural Resources Committee
John Holden, Ford Motor Company
Paul Root, General Motors Corporation

Mr. OTTINGER. We will hear last from Mr. Buckner.

## STATEMENT OF MICHEAL BUCKNER

Mr. BUCKNER. My name is Micheal Buckner. I am an underground coal miner from West Virginia and currently serve as manager of the research department for the United Mine Workers of America.

On behalf of the UMWA I would like to thank you for the opportunity to present our views on a subject of vital importance to our Nation—the utilization of domestic coal reserves to reduce our dependence on foreign oil.

Before I get started, I would like to convey a message from Mr. Church. He was very interested in this hearing. But as you may know, our current national contract with the bituminous coal operators expires March 27 of next year.

Mr. Church is busy right at this moment finalizing our package of proposals in the hope that with an early start on the negotiations we can conclude a contract without resorting to a nationwide strike.

He wanted me to convey to you that he appreciates your interest in our views and wanted me to tell you he is very interested in the work of this subcommittee.

Mr. OTTINGER. Thank you very much.

Mr. BUCKNER. As you know, Mr. Chairman, the UMW is keenly interested in our Nation's energy future and its relationship to the members of the UMW as citizens and as workers. We have advocated legislation and regulation which will not only result in employment opportunities for coal miners but will reduce our dependence on foreign oil supplies.

In spite of our efforts, however, there exists an anomaly in the coal industry today. While our Nation struggles to come to grips with an ever-threatening energy problem, over 200,000 UMWA coal miners are without work and thousands more are working short weeks.

In 1980 the U.S. coal industry will once again break all-time coal production records by mining more than 800 million tons. Despite this fact, the industry still has an unused production capability in excess of 100 million tons.

It is clear to the UMWA that the full potential of coal is not being realized in our efforts to reduce dependence on foreign oil. We have a highly trained work force, an existing supply and distribution system, and more than adequate reserves to substantially reduce that dependence. What we need are Government policies and industry initiatives that will allow coal to be put to its full potential.

The subject of today's hearing—the production of methanol from coal—is particularly promising in that it offers us the opportunity to utilize domestic coal reserves in the transportation sector of our economy.

The lion's share of our coal production is consumed in the electric utility and industrial sectors. Only small amounts are used in the residential and commercial sector and virtually none is used in transportation.

Since transportation accounts for just over 25 percent of total U.S. energy consumption and is almost completely dependent on petroleum, it is obvious that this sector represents a significant portion of our oil supply problem.

Finding domestic sources of transportation fuel is an important energy goal. However, without the development of methanol we will have to wait for the development of synthetic gasoline or electric automobiles for coal to play a role in the reduction of foreign oil in our transportation sector.

The technology for converting coal to methanol is well known and presents no insurmountable technological problems. The United States currently produces over 1 billion gallons of methanol per year from natural gas. The produce is used to make glue, plastics, synthetic fibers and drugs.

The process of making methanol from coal can be described in a simplified way as converting the coal to a synthesis gas and then turning it into a liquid by passing the gas over a catalyst.

Liquid methanol is an extremely versatile fuel. It can be used in a variety of ways, including utility boiler fuel, industrial boiler and process fuel, and as a transportation fuel.

Since it is a stable liquid at normal temperatures, it can be transported by pipeline, railcar, barge, or tank truck. Unlike electricity or gasoline, methanol can be stored easily and safely near the point of end use.

One of the questions which will inevitably arise in the debate on methanol is the adequacy of the coal supply. The UMWA believes that this should be a minor consideration in the debate.

The United States currently consumes about 100 billion gallons of gasoline per year in private automobiles. If we assume that the initial phase of methanol use in the transportation sector will be as a blend similar in ration to gasohol, only 10 billion gallons of methanol per year would be required.

The Department of Energy estimates that methanol has a conversion efficiency of 79 percent; therefore, approximately 38 million tons of coal would be required each year.

The relative ease of providing that amount of coal can be demonstrated by looking at the unused production capabilities of the 20,000 unemployed UMWA miners. Production figures provided by the Mine Safety and Health Administration indicate that average 1979 productivity for U.S. miners was 15.2 tons per man-day.

From that figure it is clear those already trained but unemployed miners could produce in excess of 75 million tons per year if they were put back to work. This is approximately twice the amount of coal that would be necessary to produce 10 million gallons of methanol.

If we assume that the United States will eventually wish to substitute methanol for all gasoline consumption, then it will be necessary to produce an additional 300 million tons of coal per year.

At present productivity levels this could result in 100,000 new coal mining jobs. This additional production would not reduce our 300- to 400-year supply of coal significantly.

Methanol can be blended with existing gasoline supplies without significant engine modifications in ratios up to 85-percent gasoline and 15-percent methanol. Blends containing more than 15-percent methanol are possible but would require carburetor modification. Future vehicles could be designed to use pure methanol. Due to a low Btu per gallon rating than gasoline, pure methanol engines would require a fuel tank approximately double the size of gasoline engines. This would result in a slight increase in weight but would probably not exceed 3 to 4 percent of the vehicle's total weight.

Automobiles which are designed to run on pure methanol would provide several environmental advantages over gasoline engines. Because of this, methanol can allow our high sulfur coal reserves to be used in an environmentally acceptable manner.

Since the conversion process removes pollutants in a relatively small number of concentrated stationary sources instead of thousands of mobile sources, the cost and efficiency of emission control can be improved.

Among the environmental advantages would be reduced automobile emissions of nitrogen oxides, carbon monoxide and soot, or particulates. In addition, there would be no emissions of aromatic hydrocarbons such as benzene.

These environmental benefits can be realized because methanol engines can perform well over a wider range of fuel-to-air ratios than gasoline-powered engines. This means that methanol cars could run at an extremely lean fuel-air ratio which causes gasoline engines to misfire or stall.

Lean mixtures result in a reduction of all major pollutants, and since methanol engines run cooler than gasoline engines, oxides of nitrogen could be further reduced.

In addition to the environmental benefits associated with methanol use, it appears that methanol is economically attractive when compared with other alternatives. The recent Office of Technology report, "Energy From Biological Processes," compared the economics of several gasoline alternatives including methanol, ethanol, oil shale, and synthetic crude from coal.

The cost of refined motor fuel in each of the categories is as follows:

| FUEL SOURCE | $/MILLION BTU | $/GALLON |
|---|---|---|
| IMPORTED CRUDE | $ 9.37 | $1.17 |
| METHANOL FROM COAL | $ 5.50 - $ 8.80 | $ .35 -$ .56 |
| ETHANOL FROM BIOMASS | $10.70 - $17.80 | $ .90 -$1.50 |
| OIL SHALE | $12.50 - $16.20 | $1.56 -$2.03 |
| SYNCRUDE FROM COAL | $10.90 - $17.80 | $1.37 -$2.23 |

Mr. BUCKNER. As you can see, methanol from coal compares favorably with gasoline now and shows a substantial economic advantage over other viable alternatives.

Of course, these figures represent production costs. In order to reflect total costs, one should also consider the capital costs of plant construction. In order to produce 10 billion gallons of methanol per year, it is estimated that 20 coal conversion plants would have to be constructed.

Based on DOE cost figures, the Congressional Research Service estimates that the total cost of building these plants would be approximately $10 billion. As Chairman Dingell mentioned before, the savings would amount to something over $13 billion. So you can see that that cost should not be a significant deterrent to development of methanol.

In addition, one——

Mr. OTTINGER. Let me just stop you there. If you are comparing the present costs today, methanol presently is being produced. So, it seems to me that your cost comparison has to be more favorable.

You said you have to start over and add the construction costs.

Mr. BUCKNER. That could be construction costs for methanol from coal. The plants now are natural gas. So you would have construction costs, but I believe you are correct that the capital costs are already reflected in my estimates.

Mr. OTTINGER. There was a construction cost associated with that process. You ought to come out with a net benefit that is more favorable than you indicated. Go ahead.

Mr. BUCKNER. In addition, one should factor in the benefit of increased national security due to decreased dependence on the foreign oil.

In summary, Mr. Chairman, the UMWA believes that coal can and should play a greater role in our total energy mix. All of us are aware of the role it can assume in the electric utility and industrial sectors and now it appears that, through methanol, coal can begin to alleviate the oil supply strain in the transportation sector.

Methanol, by most indications, is technically and economically feasible now and in the long run will offer additional benefits through reductions in the level of automotive pollutants.

There is no doubt that we have adequate coal supplies, a skilled and safety conscious work force, and an existing supply and distribution system that needs minimal upgrading to handle the increased coal production.

We can decrease our oil dependence and increase our national security while, at the same time, increasing our employment opportunities here at home. In addition, we can utilize our abundant coal reserves in a manner which is compatible with our environmental goals.

All of these positive aspects indicate that methanol should receive greater attention as an alternative to petroleum-based gasoline. The UMWA looks forward to working with the subcommittee in its efforts to solve our energy problems.

Thank you, Mr. Chairman.

Mr. OTTINGER. I want to thank you very much for very useful testimony, all three of you.

Mr. McCormick, in the process of converting coal to low Btu gas and then to methanol, my understanding is you can take the large majority of the sulfur out.

Does that mean that using coal in this manner obviates the problems of acid rain that we are experiencing today and would experience with synthetic coal liquids?

Mr. MCCORMICK. Mr. Chairman, if you look at the end use of the product of low or medium Btu gasification being a boiler fuel, and that boiler fuel is going to replace residual oil, then I don't think there would be much trade off with $SO_2$ emissions.

If the product of the low or medium Btu gasification is going to result in methanol synthesis, and then that methanol be burned in an automobile, then again there won't be much sulfur dioxide, since gasoline doesn't have sulfur dioxide as an effluent.

Finally, if the product of the low or medium Btu is to provide boiler fuel for a combined cycle electric generation plant, then you are getting greater efficiency from the coal, you are removing the sulfur in the process of converting the coal to the boiler fuel gas, and therefore you have virtually no $SO_2$ emissions upon converting that fuel into electricity essentially.

Mr. OTTINGER. That testimony is very useful. The thing I wanted to get on the record, though, is that using the coal as an automobile fuel, taking it through the low Btu gas methanol cycle will not add any problems of acid rain.

Mr. MCCORMICK. Right, it will not. It will give us an opportunity to use a significant amount of medium- and high-sulfur coals, coals which have difficulty finding their ways into the markets.

Mr. OTTINGER. Mr. Hunt?

Mr. HUNT. Thank you, Mr. Chairman.

Mr. McCormick, it is our understanding—let me address this to the entire panel—that methanol, by virtue of the additional OH radical within the molecule, has a tendency to burn at a much lower temperature than gasoline, and this lower-flame temperature reduces the $NO_X$ emissions, which are also a contributor, to the acid rain problem.

Is that correct?

Mr. MCCORMICK. That is my understanding also. I would concur with that view.

Mr. OTTINGER. The last question—if you look at the overall process, the increased mining of coal, gasification, methanol production, the final use in automobiles, what are the net environmental effects of going to increased use of methanol as opposed to continued reliance on conventional petroleum products, shale, or other coal synthetic products? Where along the chain do we get hurt the most environmentally and where do we gain the most?

Mr. McCormick. Mr. Chairman, I would like to submit a more comprehensive statement for the record, but I will say that in my understanding of the process of converting shale to a crude, a synthetic crude, the environmental problems are mind-boggling in my estimation.

When I look at low and medium Btu coal gasification as a process of converting coal into methanol, I concur with the view of the representative from the United Auto Workers that this could be a decentralized process, small coal feed requirements, therefore you are diminishing the environmental impacts of the process.

I think it is far more manageable than the other coal liquefaction or oil shale processes that we are aware of.

Mr. Ottinger. All right.

For Mr. Luria—I am not sure you are the right person—we heard testimony—I think you were here this morning—about the vastly improved engine that Texaco and White Engines have developed.

Why doesn't—or maybe they do the UAW include in its bargaining, since its jobs are on the line, that the U.S. automobile companies move into this kind of an area? That is, the incorporation of more fuel-flexible and more efficient engines into the U.S. automobile.

Mr. Luria. Well, I think it is a planning problem. The planning problem is simply this. As this committee heard last year in testimony on some related issues, the auto industry would be pleased to produce engines which ran on methanol. In fact, they would prefer, I should add, to run on pure methanol rather than on blends.

On the other hand, they say, "How do we have any assurance that the petroleum industry, or more broadly defined the liquid fuels industry, will make fuels available?"

Mr. Ottinger. This engine runs on anything. It will run on gasoline. It will run on coal, on heavy oils, on cabbage, sweet peas, virtually anything at all. It seems to me that would be tremendously advantageous because Detroit could produce an engine that could accommodate whatever fuels and we would be ahead of the game for a change.

Mr. Luria. Let me tell you the political problem that raises. I would think Chrysler would agree with you, that Ford would look at the investment it has in its programed combustion engine systems, which are slightly different than the TCCS system, and General Motors would look presumably at its tremendous fixed costs already embedded in its diesel programs.

So, in a sense, if I was going to make a wild guess, I would have to say that General Motors is probably more interested in the development of shale because it is a very good feedstock for diesel fuel, and that Ford would probably be much more interested in this kind of a system than would General Motors. Chrysler I assume would be willing to go to whatever the cheapest engine and cheapest fuel would be.

Mr. Ottinger. Well, even that would be very advantageous. At the present time there is a big imbalance in the U.S. market.

Granted certainly Chrysler, I guess Ford also, might need some financing help, but it seems to me that is something that would be very worthwhile from the national point of view and from the company's point of view as well.

It seems to me that the UAW, with whom I am very closely associated, ought not just be looking at how much money it is going to get out of its employers in its next contracts—and that doesn't look very promising from Chrysler—but rather how they can really expand the U.S. auto production's share of the pie. This looks like a very promising area.

I will feed the bug into Mr. Fraser's ear myself. I would think at all levels this is something worthwhile for the auto workers to pursue.

Mr. LURIA. I agree with you, and I will convey those remarks to Mr. Fraser.

Mr. OTTINGER. All right. I want to thank you all very much. I wish we had a little more time with you.

We will resume the subcommittee at 1:30 this afternoon. We have two additional panels of witnesses. We will recess at the present time.

[Whereupon, at 12:30 p.m. the subcommittee recessed, to reconvene at 1:30 p.m., the same day.]

AFTER RECESS

[The subcommittee reconvened at 1:30 p.m., Hon. Richard L. Ottinger, presiding.]

Mr. OTTINGER. We are exploring the potential of methanol as a very advantageous fuel for the country with a panel on the technical and international aspects of the problem, followed by a panel that consists of various congressional research organizations looking into the matter.

The first panel this afternoon will be professor Richard Pefley, chairman of the Department of Mechanical Engineering of the University of Santa Clara; Dr. Thomas Reed, senior scientist, Bio/Chemical Conversion Branch, Solar Energy Research Institute; Mr. Jerome Marten, Davy McKee, Inc., Fla.; and Mr. G. Torrence Flint, president of the Badger Energy, Inc.

Gentlemen, I appreciate your coming, particularly at this hectic season of the year. We will put your full statements in the record and would appreciate the extent you can summarize your statements.

**STATEMENTS OF RICHARD K. PEFLEY, CHAIRMAN, MECHANICAL ENGINEERING DEPARTMENT, UNIVERSITY OF SANTA CLARA; THOMAS B. REED, SENIOR SCIENTIST, BIO/CHEMICAL CONVERSION BRANCH, SOLAR ENERGY RESEARCH INSTITUTE; JEROME H. MARTEN, DIRECTOR OF TECHNOLOGY, DAVY McKEE CORP.; AND G. TORRENCE FLINT, PRESIDENT, BADGER ENERGY, INC., ACCOMPANIED BY DAVE JONES, VICE PRESIDENT OF TECHNOLOGY**

Mr. PEFLEY. Thank you, Mr. Chairman. It is my pleasure to be addressing you this afternoon.

We have been operating pure methanol vehicles since 1970, 14 months ago we had pure alcohol vehicles and one blend vehicle on display at the Rayburn Building. However, it is my opinion that the United States has slipped in its leadership in assessing alternate fuels during that 14 months. Let me be specific.

As chairman of the International Organizing Committee, I participated in the Fourth International Alcohol Fuels Technology Symposium which was held in Guaruja, Brazil in October of this year. It was attended by approximately 500 representatives from 40 countries; 4½ years ago the first international symposium was held in Stockholm, Sweden. It was attended by approximately 50 representatives from nine countries. The nations of the world appear to be looking with growing interest at the alcohols as alternatives to petroleum.

Although a major topic was alcohol in diesels in the fourth symposium, not one U.S. diesel energy manufacturer presented a paper there.

Research relative to the alcohols as transportation fuels indicates that on total assessment performance, emissions, environmental factors, and safety, they are in several ways superior to their petroleum counterparts. Two examples are carbon free combustion and high octane numbers.

If you rank the fuels in this sense, you will find that methanol typically has the highest octane number, is the cleanest burning, and gasoline is the poorest, with ethanol falling in between.

While not superior in every aspect, research projects have clearly established them as prime candidate fuels for ground and marine transportation. It is also evident that they can be produced from a variety of sources: biomass, coal, and natural gas. Hence, they offer opportunities for domestic production in many countries. When we look at the transportation systems of the world, we realize that they have many commonalities. The commonalities of these transportation systems rest in significant part on the fact that we are using a common fuel, petroleum, and so as we address alternate fuels, it seems imperative that we look for alternate fuels that can be produced throughout the world, otherwise our transportation systems become individualistic and very expensive in comparison.

What I would like to do is make some summarizing statements which are defended in the text that I have submitted in the hopes that they will provoke some discussion.

From the most recent investigations of alcohol as alternate fuels, some significant observations can be made. Alcohols can be used to extend gasoline supplies and it is recommended that all new cars sold in the United States be able to accept 5 percent methanol and 10 percent ethanol blended in gasoline and meet all new car mileage, emission and warranty standards.

The use of such blends allows elasticity between alcohol production and consumption as the blend can vary within the bounds without performance degradation.

Let me cite a specific for instance. We currently have one car that we are operating on blends. It has a slight electronic modification to it. With that electronic modification it is able to handle any combination of methanol or ethanol blended in gasoline and meet all California emissions and mileage standards for the year. In effect, there are cars that are currently available that will handle wide ranges of alcohol gasoline mixtures.

This car actually can handle a phased separated fuel. One of the concerns with the blended fuel is that the alcohol will separate from the gasoline. What happens in cold weather if the fuels separate? It has a short period of low power output while it is running primarily on alcohol. The fuel pump remixes the alcohol-gasoline mixture such that it can then go on and perform on the remixed fuel quite satisfactorily.

So in the blend area, what we look for is a car that can handle any combination of alcohol and gasoline because that gives the operator the best of all worlds, and if the manufacturers have certified that these cars can use alcohol mixtures in their fuel engine systems, why, I think the consumer has a good break at that point.

The physical and chemical properties of alcohol can best be exploited, however, by using them in pure form. Engines designed expressly for these fuels are in the preliminary study phases. We heard about a possibility this morning. It is expected the power and efficiency of such engines will be significantly better than gasoline. It is conjectured that if we really re-engineer the engine for pure methanol, we might be able to get the same miles per gallon out of that methanol engine as we are currently getting out of gasoline, even though you only put half as much energy in the fuel tank.

The regulated emissions from engines designed for alcohols can be as low or lower than gasoline and we believe the photochemical reactivity is lower. Today in California you get a credit if you use propane because it has a low photochemical reactivity compared to the gasoline exhaust. Methanol has a lower photochemical reactivity than propane and it is the primary hydrocarbon output from an alcohol or methanol fueled engine.

The forthcoming California Commission fleet program may be the most significant vehicle project in the world as it is attempting to meet 1982 emissions, 1985 mileage standards, with pure alcohol fuels. Mr. Ken Smith of the California Energy Commission is in the audience just to make you aware of his presence.

I would like to briefly read from a news release relative to that project.

> December 19, pure methanol will flow from special pumps at a service station here into the first of a fleet of State cars that will use the synthetic fuel during a 3-year test program. Today's fueling operation kicked off the $2 million program being conducted by Alcohol Energy Systems for the California Energy Commission.

Relative to diesels, there was a great deal of discussion in the fourth symposium about diesels because the Third World countries are being impacted with these petroleum prices more in the diesel sector than in the gasoline sector. They have far more need for diesel than for gasoline because the balance between trucks, buses, and cars is quite different from ours.

So there was much discussion and some fascinating evidence that turned up at this symposium. We think diesel engines can be operated on combinations of alcohol and diesel fuels by fumigation of the alcohols, by injection of alcohol diesel fuel emulsions, or by a separate injection of the two fuels.

The use of pure alcohols in diesel engines offers the best opportunity for reducing smoke and odor. If you burn the pure alcohols, there are essentially no particulates. We think this is a great advantage. In Brazil I observed the operation of both a small and large diesel. A small Toyota Land Rover with a Mercedes diesel running on alcohol and a large bus. The exhaust is a nice friend. It smells good. There are no particulates coming from it. It could make a good neighbor out of a city bus. However, it does require engine modification such as a spark plug ignition unless cetene improvers are added to the alcohols. We heard discussion related to that this morning. The engine they were talking about this morning is such a hybrid engine. We do believe, if pure alcohols are used, that the spark ignited engine and the diesel will come together. There will be some aspects of each that will be incorporated finally in the best form of alcohol engine.

In conclusion, it is my impression that it will be recorded in history that the United States benefited most from the petroleum resources of the world. Will it also be recorded that the United States used part of its industrial might to put in place an attractive alternative as petroleum supplies diminished, thereby avoiding major economic dislocations throughout the world?

I hope the answer to that question is "Yes." I will be happy to answer any questions you might have relative to my comments.

[Testimony resumes on p. 191.]

[Mr. Pefley's prepared statement follows:]

STATEMENT OF RICHARD K. PEFLEY, CHAIRMAN, MECHANICAL ENGINEERING DEPARTMENT, UNIVERSITY OF SANTA CLARA

The Fourth International Alcohol Fuels Technology Symposium was held in Guaruja, Brazil in October of this year. It was attended by approximately 500 representatives from 40 countries. Four and one-half years ago the First International Symposium was held in Stockholm, Sweden. It was attended by approximately 50 representatives from nine countries. The nations of the world appear to be looking with growing interest at the alcohols as alternatives to petroleum.

Research relative to the alcohols as transportation fuels indicates that on total assessment--performance, emissions, environmental factors and safety--they are in several ways superior to their petroleum counterparts. Two examples are their carbon free combustion and high octane numbers. While not superior in every respect, research projects have clearly established them as prime candidate fuels for ground and marine transportation. It is also evident that they can be produced from a variety of sources--biomass, coal and natural gas. Hence, they offer opportunities for domestic production in many countries.

It is currently recognized that both ethyl alcohol (ehtanol and methyl alcohol (methanol) as well as other alcohols and ethers can be blended with gasoline to extend its availability. The blending can be done in the refinery by re-engineering the blend constituents to give vapor-pressure patterns similar to gasoline. Alternatively, they can be blended after the refinery without modification. There are benefits and problems associated with each mode. It is possible to accommodate the levels of 5% anhydrous methanol or 10% ethanol as gasoline extenders. The results are minor changes in fuel economy, performance and exhaust emissions. There can be problems with alcohol gasoline blends such as materials compatability and excessive vapor pressure but they are not insurmountable and blends are being sold commercially today. Thus, alcohols are seen as feasible gasoline extenders and might prove to be better as a strategic reserve than stockpiling foreign oil. Vehicle tolerance for these blends allows elasticity in consumption of alcohol in the United States from 0 to 5 million gallons of alcohol per day at the 5% blend level and we have recommended legislation requiring all new cars to handle such blends without modifications while maintaining warranties and emissions standards.

Recognizing the utility of blending alcohol, the question then arises, is it possible to find a fuel and engine system in the automobile fleet which is capable of or can be adapted to the use of a wide variety of alcohol-gasoline blends? A 1980 Toyota Cressida with electronic fuel injection and a three-way catalyst has been tested at the University of Santa Clara using a broad range of methanol and ethanol blends in gasoline. The test data indicates that with a simple electronic modification of the fuel injection controller, the Cressida is capable of accommodating any ethanol/gasoline blend or methanol/gasoline blend and the pure alcohols, while continuing to meet Federal exhaust and evaporative emissions standards. Although volumetric fuel economy (miles per gallon) declines for the blend conditions, the energy economy (miles per million BTU's of fuel energy) is unchanged for all of the fuels.

One issue which arises from alcohol blending is the phase separation of the fuel due to the presence of water, as performance can be impaired to the point of engine stoppage. However, the Cressida provides a possible solution as it has encountered phase separation of the fuel in road operation and handled the problem successfully. The fuel system has an electric pump which provides fuel circulation between the tank and the injection system. Upon starting with phase separated fuel, there is a short duration of the lowered engine power while the fuel system remixes the alcohol with the gasoline. Normal performance is then restored. Attention to this as a design issue may allow for satisfactory operation with phase separated fuel over a wide blend range.

A second issue is materials compatibility. The fuel tank with its terne plate coating, the fuel delivery system and the engine components all have metal and non-metal parts which may be subject to attack by corrosion, erosion and distortion. It is generally agreed that small percentages of methanol require the greatest materials modifications. Materials compatibility sorting is rapidly taking place and limited experience with pure methanol shows long survival rates for some current models. However, some lubrication problems need attention.

The attractive properties of the alcohols as spark-ignited engine fuels are several. Their high octane numbers* (ethanol 98-102 and methanol 99-102), low $NO_x$ emissions, carbon-free combustion and greater lean burning compatibility

*Pump octane number which is the average of reserach and motor octane.

relative to gasoline cannot be fully exploited when they are blended with gasoline. The higher octane numbers for the alcohols allow greater power and thermal efficiency through increased compression ratio while their higher heats of vaporization allow increased cooling of engine parts. The net result is an opportunity for engine downsizing without sacrifice in peformance and a gain in fuel economy.

The best way to use pure alcohols is to redesign the engine to exploit the unique properties of alcohols, which are: carbon-free combustion, high heats of vaporization and octane numbers. This will allow more power from smaller engines--a savings in manufacturing costs because of lower vehicle weight. It will allow improved engine efficiency--a further saving in fuel. The cooling system of the engine can be significantly reduced, a further saving in manufacturing cost and a smaller vehicle frontal drag area. How far these trends can be carried if the engines are expressly designed for alcohol has yet to be fully assessed. Because cylinder deposits, spark plug fouling and similar design uncertainties are reduced due to the clean burning characteristics of the alcohols, it is predicted that current engine adaptations to alcohol represent only the initial phases of this design evolution.

Design considerations of spark ignited engines operating on pure alcohols must include three important areas: the cold starting ability, the control of aldehydes, and fuel system and engine materials and lubrication compatibility. There is general agreement that aldehydes form alcohol engine exhausts (formaldehyde from methanol and acetaldehyde from ethanol) are higher than from gasoline, particularly in the lean burn region. It is also recognized that hydrocarbon exhaust catalysts effectively remove 80 to 90% of the aldehydes. The design of an alcohol fueled vehicle with aldehydes as low or lower than gasoline is one of the goals toward which we are dedicating a significant portion of our laboratory engine and computer modeling studies. However, it is important to realize that the photochemical reactions of the hydrocarbons from the gasoline fueled vehicle create significant amounts of formaldehyde in our atmosphere while the unburned fuel from the exhaust of alcohol fueled vehicles does not. Hence, the total contribution to atmospheric aldehydes may not be seriously altered by the use of alcohols. Nonetheless, if aldehyde levels were reduced it could be said unequivocally that alcohol fueled vehicles have lower emissions than gasoline.

Current production plans call for hundreds of thousands of ethanol fueled vehicles to be built on the same assembly lines as gasoline fueled vehicles by the automobile industry of Brazil. Marketing of these cars at the same price as gasoline models clearly indicates that major changes in materials and lubricants are not foreseen in the use of pure ethanol.

Pure methanol usage conducted by our research group involves several vehicles, including a 1972 Plymouth with a slant-six engine. This vehicle was used by the meter readers of the City of Santa Clara for 8-1/2 years, traveling 50,000 miles with ten stops and starts a day. This vehicle has been torn down and inspection revealed that the combustion chambers are free of carbon deposits. With two exceptions, all of the engine parts were found to be within the original manufacturer's tolerances for new parts. In another test program, a small fleet of Pinto vehicles has been run on methanol for a year. While the metals accumulation in the lubricating oil did not appear excessive, there is now significant evidence of upper cylinder wear such as to require oil changes before the 10,000 miles interval recommended for gasoline. This evidence is being assessed. Oil change frequency, type of oil and materials compatability are all being assessed.

While pure alcohols are excellent spark ignition fuels, they are currently poor diesel fuels due to their low cetane numbers which means that they will not even ignite in a diesel engine. Thus, ethanol and methanol must be provided with an ignition source in diesel engines such as a spark plug, glow plug or chemical cetane boosters. In addition, they gave poor lubricity and this may require modifications of fuel injection systems.

Due to the difficulty of using pure alcohols in diesel engines, alcohol-diesel fuel blends have been tested more extensively. Such "blends" may take the form of solutions and mechanically induced or chemically stabilized solutions. Additionally, alcohols can be added to the intake air (fumigation) with pilot ignition by the injection of diesel fuel, or alcohols and diesel fuel can be injected separately.

Methanol and ethanol have also been added to the diesel engine intake air to supply up to 30% of the energy requirements. In these applications, hydrocarbon emissions generally increase or decrease depending on the overall air fuel ratio and relative amounts of alcohol and diesel fuel.

Smoke or particulate emissions appear to be decreased with fumigation but the particulates may become more biologically active.

While the amount of alcohol which can be mixed with diesel fuel or fumigated is limited by the onset of ignition problems, the use of dual injection systems allows up to 80% of the energy to be supplied by methanol. In the application the diesel fuel is injected and ignites first providing a pilot ignition source for the methanol. Finally, pure alcohols can be used in diesel engines with the addition of spark plugs or glow plugs for ignition. Emissions of HC are about the same, and $NO_x$ is lower than for pure diesel operation while smoke is nonexistent and even aldehyde emissions are low.

Any reasonable assessment of alternatives to petroleum-based fuels should include considerations of environmental, health and safety factors, not only in the production of the fuels but in the distribution and use as well.

The exhaust emissions of the alcohols and their photochemical reactivities in comparison with gasoline have received preliminary examination. The alcohols are also being studied in terms of toxicological consequences of major marine and land spills in comparison with petroleum. Preliminary studies of the effects of alcohol absorbtion, inhalation and ingestion on the human system are also underway.

To date, the aggregate preliminary evidence indicates to the author that the alcohols will create less environmental pollution and health hazards than the petroleum which they will replace. However, continuous assessments of these factors comparing the alcohols with liquefied coal and oil shale based fuels and existing petroleum products must be carried out to determine if the alcohols are the most cost effective of all altneatives to petroleum for our surface transportation when performance, environmental health and safety are included in the assessment.

From the more recent investigations of alcohols as alternative fuels some significant observations can be made:

(1) Alcohols can be used to extend gasoline supplies and it is recommended that all new cars be able to accept 5% methanol and 10% ethanol blended in gasoline and meet mileage and emission standards. The use of such blends allows elasticity between alcohol production and consumption as the blend can vary within bounds without performance degradation.

(2) The physical and chemical properties of alcohols can best be exploited by using them in pure form. Engines designed expressly for these fuels are in the preliminary study phase. It is expected that the power and efficiency of such engines will be significantly better than gasoline.

(3) The regulated emissions from engines designed for alcohols can be as low or lower than gasoline and their photochemical reactivity is expected to be lower.

(4) The forthcoming California Energy Commission alcohol fleet program may be the most significant vehicle project in the world as it attempts to advance the state of the art in alcohol engine performance and emissions.

(5) Diesel engines can be operated on combinations of alcohol and diesel fuels by fumigation of the alcohols by injection of alcohol-diesel fuel emulsions or by separate injection of the two fuels. The use of pure alcohols in diesel engines offers the best opportunity for reduction of smoke and odor. However, it requires engine modifications such as spark plug or glow plug ingition unless cetane improvers are added to the alcohols.

(6) It will be recorded in history that the United States benefitted most from the petroleum resources of the world. Will it also be recorded that the United States used part of its ensuing industrial might to put in place an attractive alternative as petroleum supplies dwindled, thereby avoiding major economic dislocations throughout the world.

Mr. OTTINGER. Thank you, very much.

Dr. Reed?

## STATEMENT OF THOMAS B. REED

Mr. REED. Mr. Chairman, it is a pleasure to be here this afternoon to talk on my favorite subject.

My name is Dr. Thomas B. Reed, I am a chemist, and chemical engineer by training. I have been particularly interested in alcohol fuels since 1973, at which time I began using a 10-percent mix of methanol or ethanol, in my family cars. Early this year I converted one of my cars to pure methanol.

It is nice to practice what you preach, but really my field of expertise is more in the field of production of alcohols rather than the use in engines. I will leave that field to Dick Pefley here. So I would like to say a few words about methanol production from biomass.

I have submitted some written oral testimony to the committee. I will interpolate some oral testimony. [See p. 195.]

Why should we think about converting the country to an alcohol fuel when traditionally we have been geared to run on petroleum?

Well, the first thing, it is not a very large change. You are talking about minor machining changes, minor materials changes and so forth. Gasoline, while it is not a perfect fuel, at the right costs and coming out of our ground has been is a pretty darned good fuel. We have all enjoyed and gotten fat on the luxury of low cost fuels such as gasoline. I think that is about over.

Gasoline coming from other countries in a thin stream of black tankers with a thick stream of greenbacks going the other way is certainly a threat to our national security and the world money system. So I hope that we can sever that dependence as soon as possible.

Taking the longer view—I don't know whether it will occur in my lifetime, but I understand that somewhere beyond the year 2000 the United States will essentially have run out of the oil it needs for its own uses and the world will probably run out somewhere around 2050—ultimately we have to solve the problem of what liquid fuel do we use next? What synthetic liquid fuel do we use?

We could, of course, make a synthetic gasoline. Hitler proved that can be done. But it is done at a high price. If gasoline was the perfect auto fuel, I would recommend doing that.

But, in fact, if you are going to have to synthesize a fuel, from the viewpoint of the automobile engine alcohol really is a better fuel to go for. It will burn more efficiently and more cleanly in the engine. Maybe in Hitler's Germany that wasn't very important, but certainly for ourselves and our children and grandchildren that will be very important.

The high octane, in particular, is one of the features which is at least in today's engines one of the most important parts, whether you put it in as a blend or as the major component. It can also be used as peaking fuel.

So half the reason is that alcohols fit the various uses we have in mind. The other half of the reason is that we can make ethanol, methanol and other alcohol fuels in commercial quantities using commercially available processes. Many other processes that we hear wonderful things about are really not tested and tried out and we estimate leadtimes of 10 to 15 years for synthetic coal liquids and shale oil. We are already producing ethanol in increasing quantities. Methanol could also be produced in 5 years from coal or biomass. The importance of that short lead time cannot be overestimated.

What are we going to make the alcohol fuel from? Well, wearing my patriot's hat, I would say we should make alcohol from whatever we can find as soon as possible to reduce oil imports. Methanol can be made from natural gas in isolated deposits where we can't afford a pipeline. It could certainly be from coal, and I believe we should start such plants today. However, if that was the extent of my message only, I wouldn't be at the Solar Energy Research Institute. I would not be here today talking about somewhat smaller production plants using biomass as a feedstock.

Conventional wisdom, which is based largely on the last century's experience, says that coal is marginally better than wood as an energy source. One hundred years ago, in 1880, we were obtaining three-quarters of our energy from wood, and coal was being developed, rapidly. By 1920, wood use had gone down significantly and coal was still increasing. Both coal and wood were displaced by oil and gas in this century. Now that oil and gas will soon be gone, do we go back to coal? Or should we reconsider before we make that assumption without testing it?

I would like to give you a few reasons why I think at least in many parts of the country biomass can compete with coal as a feedstock for synthetic fuels or just for heat and other uses.

I will give you a few examples of uses where biomass is already demonstrating it competes with coal as an energy source. I will then extrapolate to say in making synthetic fuels it can also compete also.

Biomass is the principal energy source for instance, in the paper and lumber companies which are presently generating something like 1½ percent of U.S. energy from wood.

As a second example, farmers in the Midwest are beginning to look at bale burners. They will bale up their hay and they will then put them in what is called a bale burner to supply process heat for hot water or drying crops or grain. In the Midwest you can buy coal. If coal was superior and economically highly favored for that application, they would do that. But the fact that the farmer has the straw and there aren't five middlemen between him it means that he favors using the straw.

As a third instance, in upper New England, in Vermont, and New Hampshire, I understand that greater than 50 percent of all the homes are completely heated with wood as an energy source. Fifty years ago those houses might have been using coal because it was so cheap to put a man underground digging out coal that hacking wood with an ax couldn't compete. However, there has been a tremendous change of technology since then, first in the chain saw, but more importantly whole tree chipping and large machines which can harvest wood the same way we already harvest agricultural crops.

Another reason that biomass can compete with coal is our realization that the burning of coal does create an environmental problem even in small towns. I am not saying that biomass will be preferred everywhere, but I am saying that in many places biomass will be the preferred fuel.

Finally, in spite of all the wonderful projections of the energy savants that our energy would come from nuclear and coal, the first synthetic fuel to come online in this country has been ethanol from corn. I don't think that we can grow enough corn in this country to supply all our liquid fuel needs, but I think that this has demonstrated the ability of biomass to compete, at least in certain situations, with coal as an energy source.

Don't think that I don't also recommend coal. I think we should build 5,000-ton-a-day coal plants to make methanol as soon as possible. I am giving reasons why we should simultaneously work toward biomass as a feed stock.

We now come to the question which Mr. Hunt asked me very specifically to address: What is the appropriate scale for biomass plants to make methanol out of biomass? As you will hear, I think from the next speaker, an appropriate scale for coal might be on the order of 5,000 or 10,000 tons a day. That is appropriate for coal.

However, the appropriate scale for biomass will be much smaller for a number of reasons. First, there is the distribution of the biomass itself. The Sun shines everywhere. Plants grow everywhere. There is pretty much a thin "seam" of biomass over the whole country. It is not concentrated in West Virginia and Wyoming like the coal is. Therefore, the smaller the plants you make, the less distance you need to haul it, and the more plants you can put in to supply methanol to each area.

When I buy methanol at $1 or $2 a gallon for my car, probably there are three or four middlemen between me and the production. If you can produce it on a smaller scale in each region, you cut out the middlemen, you cut out the transportation. That is not a technical reason, but that is one of the social factors favoring small plants.

There are also technical factors favoring small biomass plants. Biomass is technically much easier than coal to turn into carbon monoxide and hydrogen which is the synthesis gas you need to make methanol. Biomass has a very high volatile content and the charcoal is very reactive. Technically it would be very difficult on a small scale to gasify coal to supply a methanol plant, but biomass can be gasified in relatively small units.

It is too early to decide exactly what size biomass plants we are talking about, but I am now designing a plant on the order of 250 to 1,000 dry tons a day of wood or corn cobs to make on the order of 400 to 500 tons a day of methanol. I believe that will turn out to be the right size.

Large paper plants in the United States typically burn four or five times as much wood for energy and an equal amount for making paper, but they are uniquely situated in the forest. If we want to put a biomass based methanol plant at farm co-ops, for instance, then we will need to make it somewhat smaller.

What are we doing at SERI to design such plants? I have believed this is a worthy goal for 6 years. What is the weak link in making a small methanol plant? So far it has been the gasifier. Gasifiers typically take wood or coal and convert them into either a low Btu gas using air or into a medium Btu gas using oxygen.

Several years ago people were considering that the PUROX gasifier built by Union Carbide might be the basis of a biomass type plant. It was designed for municipal wastes, but wastes are not very different in composition from wood. Early projections of costs of plants were based on the very limited experience with municipal wastes.

At SERI we are developing a gasifier which we believe will be the simplest form of gasifier for biomass.

At SERI we are halfway through testing the gasifier which we believe will be the prototype of the small biomass gasifier.

Before I close, I would like to call your attention to one very important synergism between making methanol and the great farm system in the United States. I would like to call to the attention of the farmer that any plant which produces methanol can also make ammonia. The farmer is not tuned in yet on methanol, but he is certainly tuned in on ammonia. Presently, 4 percent of U.S. natural gas is used to make the ammonia which makes our farm system so efficient. The escalating cost of natural gas, it will be reflected in an escalating cost of food unless we can base the manufacturer of ammonia on farm residues.

We are now planning a skid-mounted, mass produced 100-ton-a-day methanol/ammonia plant. This plant would be located at a typical farm co-op, would be fully automated, very little attention required. Most of the year the farmer would bring in his residues, and the co-op would sell methanol made in this plant.

But for about 10 to 15 percent of the year, the gas used would go to making ammonia in the spring which he would put back on his fields. This, then, makes the farm energy system self-complete within a 10- or 20-mile radius rather than having to use natural gas or the ammonia we are now buying from Russia.

I will also comment on the impact of producing small methanol ammonia plants which could be shipped skid-mounted, easily shipped anyplace in the world. I think that not only could we stabilize U.S. agriculture by using energy sources close to the farm, but we could do the same thing for many other countries in the world where the key ingredient missing from an efficient agricultural system is ammonia.

In addition to our gasification program at SERI which deals with the production of the methanol, SERI has quite a sizable program trying to demonstrate a dissociated methanol car. When you make methanol, a great deal of energy is released in the plant. In burning methanol in an automobile, you have the opportunity of reversing that process to conserve energy. Exhaust heat, which normally is wasted, can be used to dissociate methanol back into a mixture of carbon monoxide and hydrogen which will burn even more efficiently than methanol. This effectively becomes a low temperature bottoming cycle. This project is described more completely in the written testimony submitted here.

In conclusion, I would like to thank you for the opportunity to testify on these matters which are close to my heart and close to the country's most vital interests.

[Testimony resumes on p. 204.]

[Mr. Reed's prepared statement follows:]

STATEMENT OF THOMAS B. REED, SENIOR SCIENTIST, BIO/CHEMICAL CONVERSION BRANCH, SOLAR ENERGY RESEARCH INSTITUTE

MR CHAIRMAN:

IT IS AN HONOR TO ADDRESS THE DISTINGUISHED MEMBERS OF THE SUBCOMMITTEE ON ENERGY AND POWER ON THE OPPORTUNITIES TO UTILIZE METHANOL FROM RENEWABLE RESOURCES.

MY NAME IS DR. THOMAS B. REED. I AM A CHEMIST AND ENGINEER BY TRAINING AND AM CURRENTLY PRINCIPAL SCIENTIST IN THE BIOMASS DIVISION OF THE SOLAR ENERGY RESEARCH INSTITUTE (SERI), IN THE CHEMICAL AND BIOLOGICAL DIVISION. PREVIOUSLY I WORKED AT SHELL OIL, UNION CARBIDE, AND MOST RECENTLY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

I HAVE BEEN PARTICULARLY INTERESTED IN ALCOHOL FUELS SINCE 1970, WHEN I BEGAN OPERATING MY FAMILY CARS ON BLENDS OF ALCOHOLS AND GASOLINE. I AM NOW USING 100% METHANOL IN ONE OF MY CARS. HOWEVER, I CONSIDER MY SPECIAL AREA OF EXPERTISE TO BE THE PRODUCTION OF ALCOHOLS, EXPECIALLY THE PRODUCTION OF METHANOL FROM BIOMASS, PEAT AND COAL. I AM HAPPY TO REPORT THAT THIS YEAR AT SERI WE HAVE AN EFFECTIVE PROGRAM IN THE FIELD OF BIOMASS AND ALCOHOL FUELS. WE ARE PRESENTLY WORKING ON A PROJECT TO DEVELOP A GASIFIER FOR SMALL SCALE METHANOL PRODUCTION AND, HOPEFULLY, WE WILL HAVE OUR FIRST GALLON OF METHANOL BY SPRING. I WILL DISCUSS THIS PROGRAM LATER IN MY TESTIMONY.

I WOULD LIKE TO ADDRESS THE KEY QUESTIONS WHICH WILL AFFECT THE FUTURE OF METHYL FUELS FROM BIOMASS:

WHY SHOULD WE DEVELOP ALCOHOL FUELS WHEN OUR COUNTRY IS GEARED TO PETROLEUM PRODUCTS?

GASOLINE IS NOT THE PERFECT MOTOR FUEL, BUT IT WAS GOOD ENOUGH WHEN PETROLEUM WAS $1 PER BARREL -- OR EVEN $5 PER BARREL -- AND WE COULD PRODUCE IT IN THE

U.S. HOWEVER OUR RELIANCE ON IMPORTED PETROLEUM FOR 47 PERCENT OF OUR LIQUID FUEL NEEDS NOW THREATENS THE SECURITY OF THE NATION AND IS ONE OF THE MOST SIGNIFICANT CONTRIBUTORS TO THE CURRENT 12 PERCENT RATE OF INFLATION.

TAKING THE LONGER VIEW, PETROLEUM IS NOT A RENEWABLE RESOURCE AND, DEPENDING ON WHOSE ESTIMATE WE HEED, WILL HAVE DISAPPEARED AS A MAJOR DOMESTIC ENERGY SOURCE BY THE YEAR 2000 IN THE U.S. AND BY 2050 WORLD-WIDE.

ALCOHOL FUELS HAVE A NUMBER OF TECHNICAL ADVANTAGES AS MOTOR FUELS, INCLUDING VERY HIGH OCTANE AND CLEANER BURNING. WE ALREADY HAVE THE TECHNOLOGY TO MAKE THEM IN LARGE QUANTITIES FROM RENEWABLE SOURCES AND COAL. THANKS TO OUR FARMERS, GASOHOL MADE FROM FARM PRODUCTS HAS BECOME AVAILABLE IN MOST CITIES, THOUGH ON A SMALL SCALE. THE OIL COMPANIES ARE NOW RECOGNIZING BOTH METHANOL AND ETHANOL AS DESIRABLE GASOLINE ADDITIVES FOR INCREASING THE OCTANE OF GASOLINE. THERE ARE TODAY A LARGE NUMBER OF BOTH BLEND AND PURE ALCOHOL FLEET TESTS UNDERWAY IN THE U.S.

METHANOL IS ALSO CONSIDERED TO BE AN IDEAL FUEL FOR GENERATING PEAK-LOAD ELECTRICITY. ALL OF THESE SIGNS ARE POINTING TO ALCOHOLS AS A MAJOR COMPONENT OF OUR SYNTHETIC FUEL PROGRAM FOR THE NEXT DECADE.

## SHOULD WE PRODUCE METHANOL FROM BIOMASS, PEAT OR COAL?

WEARING MY PATRIOT'S HAT, I WOULD SAY THAT WE MUST PRODUCE AS MUCH ALCOHOL AS SOON AS POSSIBLE FROM WHATEVER SOURCES WE HAVE, IN ORDER TO STABILIZE U.S. AND WORLD FUEL SUPPLIES AND THE WORLD MONETARY SYSTEM.

IT IS GENERALLY ACCEPTED THAT, THE U.S. HAS ENOUGH COAL TO SUPPLY OUR NEEDS FOR SEVERAL CENTURIES AND I BELIEVE THAT PRAGMATIC WISDOM SAYS THAT WE SHOULD MAKE LARGE COAL-FUELED METHANOL PLANTS, STARTING TODAY.

HOWEVER WE MUST ALSO RECOGNIZE THAT THE ENORMOUS PLANTS NECESSARY FOR COAL PROCESSING WILL HAVE 8-15 YEAR LEAD TIMES; THERE WILL BE MANY NEGATIVE ENVIRONMENTAL FACTORS ASSOCIATED WITH USING THE QUANTITIES OF COAL CONTEMPLATED FOR THESE FACILITIES; . PROJECTED COSTS AT SUCH A DISTANCE IN TIME ARE SUBJECT TO ENORMOUS ERRORS; AND THAT WE CANT'T WAIT THAT LONG FOR AN ALTERNATIVE TO FOREIGN OIL.

CONVENTIONAL WISDOM IS THAT BIOMASS, WIDELY COLLECTED ON A SMALL-SCALE, COULD NEVER COMPETE WITH ENORMOUS COAL PLANTS. THIS BELIEF IS BASED ON THE EXPERIENCE OF FITY YEARS AGO, WHEN BOTH COAL AND BIOMASS WERE PRODUCED IN VERY DIFFERENT WAYS. MANY FACTORS HAVE CHANGED WHICH CAN TIP THE BALANCE TOWARD BIOMASS AS THE FEEDSTOCK OF CHOICE FOR ALCOHOL PRODUCTION IN THE FUTURE.

THE PRODUCTION OF BIOMASS RESIDUES ON OUR FIELDS HAS INCREASED 2-5 TIMES, WITH CROP YIELDS DUE TO FERTILIZATION AND MODERN AGRICULTURAL PRACTICES (MODERN HARVEST, TRANSPORT AND STORAGE, DENSIFICATION, NEW BALING TECHNIQUES, ETC.). THESE DEVELOPMENTS CAN MAKE RESIDUES AN IMPORTANT ENERGY SOURCE AT THE FARM. SIMILAR TECHNIQUES APPLIED TO OUR NEGLECTED FORESTS CAN ALSO INCREASE FOREST YIELDS AND SOIL CONDITIONS SIMULTANEOUSLY.

PEAT COMBINES MANY OF THE BEST FEATURES OF COAL AND BIOMASS, AND THE STATES POSSESSING LARGE PEAT DEPOSITS (SUCH AS MINNESOTA AND MAINE) SHOULD CONSIDER DEVELOPING THEM.

BIOMASS IS RENEWABLE YEARLY OR WITHIN OUR LIFETIME. THIS, OBVIOUSLY, CANNOT BE SAID FOR COAL. HOWEVER, MOST OF THE WORLD'S PEAT BOGS WERE LAKES ONLY A FEW THOUSAND YEARS AGO AT THE END OF THE LAST GLACIAL PERIOD. PEAT IS BIOMASS THAT NATURE WASN'T ABLE TO RECYCLE. MINING PEAT PROVIDES THE OPPORTUNITY FOR RE-ESTABLISHING GLACIAL LAKES OR CREATING RICH FARM OR FOREST LAND.

AT THIS TIME OUR ENERGY NEEDS ARE SO PRESSING THAT WE HAVE NO CHOICE BUT TO DEVELOP ALL OF OUR SOLID FUELS, COAL, BIOMASS AND PEAT TO THE MAXIMUM LIMIT OF OUR ABILITY. AT A TIME WHEN THE U.S. IS SPENDING OVER $100 BILLION/YEAR FOR IMPORTED OIL, IT SEEMS TO US ENGINEERS RATHER SHORTSIGHTED TO FIGHT OVER A FEW MILLION DOLLARS FOR DEVELOPING RESOURCES THAT MAY REQUIRE 5-20 YEARS TO DEVELOP. WE HOPE THAT CONGRESS, DOE, AND THE SYNTHETIC FUELS CORPORATION CAN WORK TOGETHER TO DEVELOP A CLEAR PROGRAM IN SYN-FUELS FROM RENEWABLE AND FOSSIL FUEL SOURCES.

IS THERE ENOUGH BIOMASS TO JUSTIFY USING IT AS A FEEDSTOCK FOR METHANOL?

A RECENT OTA STUDY OF BIOMASS ENERGY (JUNE 1980) PROJECTED THAT WITH AN AGGRESSIVE DEVELOPMENT PROGRAM BIOMASS COULD PROVIDE 12-17 QUADS OF ENERGY (15-21% OF PRESENT CONSUMPTION) BY THE YEAR 2000. I BELIEVE THAT THIS IS A REALISTIC ESTIMATE OF THE POTENTIAL OF BIOMASS.

MORE IMPORTANTLY, BIOMASS IS A CHEMICAL, STORABLE FORM OF RENEWABLE ENERGY, AN "INSTANT COAL" THAT PUTS MUCH OF THE 2 BILLION ACRES OF THE U.S. INTO ENERGY PRODUCTION COMPATIBLE WITH PRESENT FOOD AND FIBER PRODUCTION. FOR THIS REASON, BIOMASS IS UNIQUELY SUITED AMONGST THE RENEWABLE ENERGY SOURCES FOR MAKING FUELS. I CAN FORESEE A TIME WHEN THE HIGHEST USE FOR BIOMASS WILL BE FOR PRODUCING ALCOHOL FUELS AND THAT BURNING BIOMASS MERELY TO GENERATE HEAT WHICH CAN BE OBTAINED DIRECTLY FROM THE SUN WILL BE CONSIDERED AN UNJUSTIFIABLE WASTE -- ALTHOUGH WE'RE NOT YET AT THAT POINT.

IF 50% OF THE BIOMASS PROJECTED BY OTA WERE USED IN THE YEAR 2000 TO MAKE METHANOL IT WOULD YIELD 67 BILLION GALLONS OF LIQUID FUELS. FOR PURPOSES OF COMPARISON, WE NOW BURN 110 BILLION GALLONS OF GASOLINE IN OUR RELATIVELY INEFFICIENT AUTOMOBILES. CONSUMPTION COULD DECREASE TO 50 BILLION IN THE YEAR

2000 AS CAR MILEAGE INCREASES FROM THE PRESENT 15 MPG TO 40 MPG UNDER THE INFLUENCE OF HIGH-PRICED GASOLINE, AND STATUTORY MILEAGE EFFICIENCY IMPROVEMENTS.

CAN BIOMASS COMPETE ECONOMICALLY WITH COAL AS AN ENERGY SOURCE?

A CENTURY AGO, 75% OF THE U.S. ENERGY WAS DERIVED FROM WOOD. BY 1910 MORE ENERGY CAME FROM COAL THAN WOOD, BECAUSE AT THAT TIME COAL COULD BE MINED MORE CHEAPLY THAN WOOD COULD BE CUT USING THE PRIMITIVE TOOLS THEN AVAILABLE. SINCE THAT TIME THERE HAS BEEN AN ENORMOUS CHANGE IN BOTH THE TECHNOLOGY AND SCALE OF COAL AND WOOD PRODUCTION. HOWEVER, SINCE PETROLEUM WAS CHEAPER THAN EITHER COAL OR WOOD, WE HAVE NOT RE-EVALUATED THEIR COMPETITIVE ECONOMICS.

A NUMBER OF DIRECT AND INDIRECT FACTORS WILL TEND TO MAKE BIOMASS MORE COMPETITIVE TODAY THAN IT WAS IN 1900. ONLY TIME AND TESTING CAN DETERMINE IN WHICH AREAS EACH WILL BE PREFERRED.

WE ARE ALREADY FINDING THAT BIOMASS IS COMPETITIVE WITH COAL IN MANY AREAS. THE PAPER AND LUMBER COMPANIES HAVE ALWAYS USED PART OF THEIR BIOMASS TO GENERATE ENERGY. MORE THAN HALF OF THE HOMES IN NEW HAMPSHIRE AND VERMONT ARE HEATED TOTALLY WITH WOOD TODAY. MANY FARMERS NOW USE "BALE BURNERS" TO SUPPLY PROCESS HEAT FOR FARM OPERATIONS. MOST SURPRISING OF ALL, WE FIND THAT, WITH FEDERAL AND STATE SUBSIDIES, ALCOHOL PRODUCED FROM CORN CAN COMPETE WITH GASOLINE (ALSO PRODUCED EITH FEDERAL AND STATE SUBSIDIES).

THUS, THE CONVENTIONAL WISDOM REGARDING COAL AND BIOMASS CONVERSION COSTS IS BEING RE-EVALUATED TODAY IN TERMS OF NEW NEEDS, TECHNOLOGIES, AND AVAILABLE SUPPLIES.

CAN SMALL BIOMASS PLANTS COMPETE WITH LARGE COAL PLANTS?

SINCE COAL OCCURS IN VERY LARGE DEPOSITS, IT IS TECHNICALLY FEASIBLE TO MAKE VERY LARGE PLANTS. IN FACT, THE CONVERSION OF COAL IS TECHNICALLY DIFFICULT, REQUIRING MUCH SCRUBBING AND CLEANING OF THE GAS, SO THAT LARGE PLANTS ARE NECESSITATED BY THE COMPLEXITY OF THE PROCESS.

BIOMASS OCCURS IN MUCH SMALLER QUANTITIES, BUT IN MANY MORE PLACES THAN COAL. THUS THERE IS CONSIDERABLE INCENTIVE TO MAKE AS SMALL A PLANT AS TECHNICALLY POSSIBLE. FORTUNATELY WE ARE AIDED IN THIS INTENT BY THE FACT THAT BIOMASS GASIFICATION AND PROCESSING IS MUCH SIMPLER THAN COAL PROCESSING AND THUS WE BELIEVE THAT QUITE SMALL PLANTS MAKING, FOR INSTANCE, 100 TONS/DAY (10 MILLION GALLONS/YEAR) ARE PRACTICAL. IN FACT, WE ARE NOW DEVELOPING THE GASIFIER AND DESIGN FOR SUCH A PLANT AT SERI.

WHAT IS THE SOLAR ENERGY RESEARCH INSTITUTE DOING TO DEVELOP BIOMASS METHANOL PLANTS?

IF BIOMASS IS TO BE AN IMPORTANT FEEDSTOCK FOR MAKING METHANOL, THE PLANTS WILL BE MUCH SMALLER THAN COAL PLANTS. FOR EXAMPLE, 300-1200 DRY TONS/DAY OF WOOD MAKING ABOUT 100-400 TONS/DAY OF METHANOL IS AN IDEAL SIZE FOR A BIOMASS CONVERSION FACILITY (10-40 MILLION GALLONS/YEAR). LARGE PAPER PLANTS ARE OFTEN SEVERAL TIMES LARGER, BUT CONSTRUCTION OF THESE SMALLER PLANTS PERMITS USING LIMITED STOCKS OF BIOMASS IN MANY MORE PARTS OF THE COUNTRY.

WE ARE NOW CONSTRUCTING AND TESTING AT SERI A GASIFIER PROTOTYPE THAT WILL MAKE IT POSSIBLE TO BUILD METHANOL PLANTS ON THIS SMALLER SCALE. A MAJOR FEATURE OF THE "SERI OXYGEN GASIFIER" IS THAT THE GAS WE MAKE HAS NO TARS OR HYDROCARBONS. IN LARGE PLANTS, IT MAY BE ECONOMICAL TO SCRUB THESE CONTAMINANTS OUT, BUT THIS GREATLY ADDS TO THE SYSTEM COMPLEXITY AND COST. WE

CONVERT ALL OF THESE UNDESIRABLE COMPONENTS INTO MORE GAS, THUS INCREASING THE PROCESS EFFICIENCY AND REDUCING COST AND COMPLEXITY. WE ALREADY HAVE ENOUGH EXPERIENCE WITH THIS GASIFIER TO BE ASSURED THAT IT MEETS THIS CRITERION. HOWEVER, MORE TESTING WILL BE REQUIRED BEFORE WE ATTEMPT A PILOT OR PROTOTYPE PLANT.

SERI IS PROCEEDING ALONG TWO COURSES TOWARD A PROTOTYPE COMMERCIAL PLANT. WE ARE NOW PLANNING TO ADD THE ALCOHOL CONVERSION TRAIN TO OUR GASIFIER AND HOPE TO PRODUCE OUR FIRST METHANOL BY SPRING. WE ARE ALSO BEGINNING DESIGN STUDIES FOR THE LARGER PLANT BASED ON THE LIMITED DATA WE HAVE COLLECTED SO FAR.

OUR SMALL "PROOF OF CONCEPT" GASIFIER HAS COST US $160,000 TO BUILD SO FAR. WE PROJECT THAT THE COST OF THE 300 TON/DAY PLANT WILL BE ABOUT $17 MILLION AND WILL PRODUCE METHANOL FOR LESS THAN 70¢/GALLON DUE TO THE SAVINGS IN PLANT COMPLEXITY AND GAS CLEANUP COSTS.

THE ROLE OF AMMONIA IN A METHANOL-BIOMASS PLANT

SO FAR I HAVE BEEN DISCUSSING METHANOL, A FUEL FOR ENGINES. I WOULD LIKE TO CALL YOUR ATTENTION TO AMMONIA, THE FOOD FOR BIOMASS, AND ITS IMPORTANCE IN ANY BIOMASS BASED METHANOL PLANT.

THE MAJOR REASON THAT WE CAN CONSIDER MAKING METHANOL FROM BIOMASS IS THE HIGH PRODUCTIVITY OF U.S. FARMS AND FORESTS. THIS PRODUCTIVITY IS THREATENED BEACAUSE IT IS BASED ON THE EXTENSIVE USE OF AMMONIA WHICH, IN TURN, IS PRODUCED FROM NATURAL GAS. AS YOU KNOW, THE COST OF GAS IS ESCALATING ALMOST AS FAST AS OIL.

IT IS IMPORTANT TO REALIZE THAT AN AMMONIA PLANT AND A METHANOL PLANT ARE VERY SIMILAR AND, IN THE PAST, MANY PLANTS WOULD PRODUCE BOTH ON A SEASONAL BASIS

MERELY BY CHANGING THE CATALYST AND SOME OF THE PROCESS VARIABLES.

WE AT SERI HOPE TO DEVELOP SMALL PLANTS CAPABLE OF PRODUCING METHANOL OR AMMONIA. THESE PLANTS WOULD BE LOCATED IN REGIONS OF HIGH BIOMASS PRODUCIBITY, SUCH AS FARM CO-OPS AND LUMBER MILLS. MOST OF THE YEAR THEY WOULD MAKE METHANOL FOR ON-FARM USE OR FOR SALE, BUT PART OF THE YEAR (TYPICALLY 5-15%) THEY WOULD CONVERT SOME OF THE BIOMASS TO AMMONIA TO ASSURE THAT NEXT YEAR'S CROP WOULD BE AS BIG AS THIS YEAR'S. IN THIS FASHION, WE WOULD MAKE THE FARMER AND THE PAPER COMPANY SELF-SUFFICIENT AND REMOVE THEIR DEPENDENCE ON OIL SHIPPED FROM OVERSEAS.

## METHANOL AND AMMONIA PLANTS FOR THE U.S. AND THE WORLD

THE VIABILITY OF SMALL METHANOL/AMMONIA PLANTS WOULD DEPEND ON MASS PRODUCTION AND AUTOMATION TO OFFSET THE DISECONOMIES OF SMALL-SCALE. DURING WORLD WAR II THE U.S. CONSTRUCTED TWELVE 50 TON/DAY AMMONIA PLANTS WHICH WERE DISTRIBUTED AROUND THE COUNTRY. WITH PRESENT TECHNOLOGY, WE COULD MAKE HUNDREDS OF THESE PLANTS FOR COMMERCIAL SALE AND TO ASSIST DEVELOPING COUNTRIES. THE DIRECT RESULT OF THIS WOULD BE PROFITS FOR U.S. INDUSTRY. THE INDIRECT -- BUT EQUALLY IMPORTANT -- BENEFIT WOULD BE THE STABILIZATION OF WORLD FOOD SUPPLIES AND ENERGY SUPPLIES. I BELIEVE THIS IS A WORTHY GOAL FOR US TO UNDERTAKE ON A CRASH BASIS, AND I HOPE THAT I WILL CONTINUE TO HAVE THE ENTHUSIASTIC SUPPORT IN THIS PROGRAM THAT HAS EMERGED IN THE LAST YEAR.

## METHANOL FUELS FOR HEAT ENGINES

THE PRODUCTION AND UTILIZATION OF ALCOHOL FUELS POSES A CHICKEN AND EGG PROBLEM. WE MUST BRING BOTH TO FRUITION SIMULTANEOUSLY. I HOPE THAT WE ARE BEGINNING TO REALIZE THAT ALCOHOLS ARE SUPERIOR AUTOMOTIVE AND TURBINE FUELS, AND THAT WE MUST TURN OUR ATTENTION TO PRODUCTION OF THESE FUELS.

I WOULD LIKE TO MENTION ONE ASPECT OF OUR RESEARCH AT SERI WHICH BEARS ON ALCOHOL FUEL USE. WHEN WE MAKE METHANOL FROM CARBON MONOXIDE AND HYDROGEN THERE IS A GREAT DEAL OF HEAT RELEASED. THIS HEAT CAN BE CAPTURED TO MAKE STEAM TO DRIVE OUR TURBINES. WE ARE NOW BUILDING IN OUR SYSTEMS BRANCH AT SERI A CAR THAT REVERSES THIS PROCESS IN ORDER TO INCREASE THE EFFICIENCY OF ALCOHOL USE IN THE CAR. THE METHANOL FUEL IS PASSED FIRST OVER A HEAT EXCHANGER TO VAPORIZE IT AND THEN OVER A CATALYST TO BREAK IT BACK DOWN TO CARBON MONOXIDE AND HYDROGEN. THIS CAN BE CALLED A "LOW TEMPERATURE BOTTOMING CYCLE" BECAUSE IT TAKES WASTE EXHAUST HEAT AT A FEW HUNDRED DEGREES AND MAKES IT AVAILABLE IN THE ENGINE AT A FEW THOUSAND DEGREES WHERE IT WILL DO THE MOST GOOD.

ONE OF THE MINOR DRAWBACKS OF METHANOL AS A FUEL IS THAT IT HAS ONLY HALF THE ENERGY PER GALLON CONTAINED IN GASOLINE. IF THE METHANOL ENGINE HAD THE SAME EFFICIENCY AS GASOLINE WE WOULD HAVE TO HAVE TWICE AS MANY GALLONS AND TWICE AS BIG A TANK FOR EQUAL MILES. HOWEVER, THE HIGH OCTANE AND CLEAN BURNING CHARACTERISTICS OF METHANOL SHOULD MAKE IT POSSIBLE TO GET AT LEAST 25-50% MORE EFFICIENCY AND MORE MILES/BTU THAN WE OBTAIN WITH GASOLINE.

THIS NEW ENGINE CONCEPT PROMISES TO BOOST METHANOL COMBUSTION EFFICIENCY AND WE HOPE THAT WE MAY OBTAIN THE SAME MILES/GALLON WITH METHANOL AS WITH GASOLINE — THAT WOULD BE DOUBLE THE CURRENT THERMAL EFFICIENCY. THIS IS A WORTHY GOAL FOR ENGINE RESEARCH AND WE HOPE TO HAVE THIS CAR RUNNING SOON AT SERI.

IN CONCLUSION

WE BELIEVE THAT WHILE COAL-METHANOL PLANTS SHOULD BE DEVELOPED, WE CAN DEVELOP SMALL BIOMASS-METHANOL PLANTS IN A SHORTER TIME; THEY WILL BE MORE

ENVIRONMENTALLY ACCEPTABLE AND THEY CAN COMPETE WITH THE ECONOMICS OF LARGE COAL PLANTS IN MANY PARTS OF THE U.S.

BIOMASS-METHANOL PLANTS CAN AND SHOULD ALSO PRODUCE AMMONIA. IN THIS WAY THEY WILL MAKE BIOMASS PRODUCTION MORE EFFICIENT.

BIOMASS-METHANOL-AMMONIA PLANTS CAN BE REPLICATED AND SENT AROUND THE U.S. AND THE WORLD. THEY WILL STABILIZE AND IMPROVE FOOD AND FIBER PRODUCTION WHEREVER THEY ARE LOCATED AND BE A VALUABLE EXPORT FOR THE U.S.

METHANOL ENGINES CAN BE UP TO TWICE AS EFFICIENT AS GASOLINE ENGINES.

THANK YOU FOR YOUR INTEREST IN THIS VITAL SUBJECT.

Mr. Ottinger. Thank you very much. Very interesting testimony, Dr. Reed.

We will hear next from Mr. Marten.

## STATEMENT OF JEROME H. MARTEN

Mr. Marten. Thank you, Mr. Chairman.

It is my pleasure to be here and to testify at these very important hearings.

I am Jerome H. Marten, a chemical engineer by training. My position is director of technology with the Davy McKee Corp. Davy McKee is a major international engineering-construction firm whose North American corporate offices are in Cleveland, Ohio, with nine principal operating centers in the United States, one of which is in Lakeland, Fla., where I am based. I have over 25 years of professional engineering experience, the last 13 with Davy McKee and have been involved with the operation and design of methanol plants for 15 years.

Davy McKee Corp. is engaged in the engineering and construction of major process facilities ranging from petroleum refineries, natural gas treating plants, petrochemical facilities to steel mills and coal processing plants. We are involved in the synthetic fuels area with programs for producing oil from shale, coal liquefaction and gasification, as well as the production of substitute natural gas and methanol from various feedstocks.

We are leaders in the area of methanol plant design. Over 50 percent of the world's existing and contracted for capacity is and will be produced in Davy McKee designed plants, among which is the largest single train facility now operating.

In our Lakeland office, at present, we currently have in the engineering or startup phase five contracts for natural gas feedstock methanol plants which, when completed, will produce over 10,000 tons per day of product.

Davy McKee has been and is currently involved in a number of technical and economic feasibility studies for the production of methanol from feedstocks such as coal, biomass, and municipal solid waste; several of the DOE-supported studies now underway are included in this number.

I would like to address the following areas in my testimony this afternoon: The flexibility of feedstock for the production of methanol; the relationships between capital, feedstock and miscellaneous cost components in the factory door price of methanol produced from coal; the production cost of methanol from coal as a function of plant size; and last, the potential for future reduction in methanol cost by improved technology versus short term initiation of production using current technology.

Methanol is produced from synthesis gas, which is a controlled mixture of hydrogen, carbon monoxide, and carbon dioxide plus inerts such as nitrogen and methane. In theory, the required synthesis gas can be produced from any feedstock that contains carbon. Thus, potential feedstocks for methanol production include natural gas, light hydrocarbons such as LPG, low octane petroleum fractions, petroleum residues, all ranks of coal and biomass.

Plant complexity and cost to produce synthesis gas increases as the hydrogen content of the feedstock decreases. Therefore, natural gas based synthesis gas plants are much simpler and less costly than coal based plants. However, the bottom line production costs as well as feedstock availability and desirability of use will dictate in the long run which feedstocks will be used for very large scale methanol production in the United States.

Addressing specifically methanol from coal plants, there is, in our opinion, proven technology available today to produce synthesis gas suitable for methanol production from all mineable U.S. coal. There appears to be very little difference in total capital and operating costs of the various demonstrated gasification systems. Overall thermal efficiencies of coal-to-methanol plants using any of these technologies are also very similar when taken on an equivalent product basis.

Individual plants will have to be optimized for specific coal feeds, however. For example, the coal preparation and gasification processes selected for a western lignite most probably will be different than the ones chosen for use on a Pittsburgh seam bituminous coal. All other sections of the synthesis gas preparation plant would be the same in concept, but would vary in capacity depending on the particular coal used.

Another point I should like to make is that the sulfur content of a particular coal, varying, for example, from 1 to 5 percent by weight, has a very small impact on the cost of methanol production. Variations in coal moisture and ash at a constant sulfur content are much more significant.

Second, the relationships between capital, feedstock, and miscellaneous costs in the factory door price of methanol production from coal.

The factory door price of methanol from coal consists of three components: Capital related, feedstock and fuel, and miscellaneous costs such as labor, catalyst and chemicals, overheads.

The capital component of cost is related, not only to the amount of capital involved but also the method of financing. For all of our examples we have used 100-percent equity financing with a discounted cash flow of 15 percent. For a 5,000 ton of methanol per

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day facility, self-contained except for coal and water supply, the capital cost component will be at least 50 percent of the factory door price when the cost of coal is $1.75 per MM Btu, or less.

Coal costs as a percentage of factory door price of methanol will vary from 14 to 30 percent, for coal costing 58 cents and $1.75 per MM Btu, respectively.

Plant labor, catalyst, and chemicals plus overhead costs account for the remaining portion of the factory door methanol price. We calculate the factory door price for methanol manufactured from $1.75 per million Btu coal is 75 cents per gallon for a plant built and operating this year. This is equivalent to producing methanol from natural gas costing $5 per million Btu for a plant built in the same time frame.

I would next like to address the production cost of methanol from coal as a function of plant size.

In all process plants, minimum capital cost per unit of daily capacity is achieved when production is done in essentially a single train facility; that is, no significant paralleling of units. We have analyzed the coal to methanol process facility shown in the appendix and concluded that based on using maximum capacity proven technology, a 5,000 ton per day methanol from coal module exhibits these characteristics: Two methanol synthesis and distillation units and three air separation units, all other processing steps having many parallel trains.

Significant production cost savings for methanol from coal plants greater than 5,000 tons per day will therefore have to be found in coal mining and transportation systems and offsites, not the coal to methanol production module itself. Investment per unit of daily capacity is essentially constant for plants from 1,500 to 2,500 tons per day, when these plants are based on manufacture of methanol from natural gas. Therefore, even the natural gas based plant exhibits a similar phenomena.

I would next like to address the potential for future reduction in methanol cost by improved technology versus short-term initiation of production using current technology.

In our opinion, there is little probability that technical improvements in the next decade will overcome the penalties of inflation and rising energy costs. It is shown in table II of the appendix that a plant constructed and in operation in 1980 will produce lower cost methanol in 1990 than a new plant completed in 1990 using assumed improved technology that reduces capital cost, 1980 dollars, by 15 percent and increases efficiency by 10 percent. Both of these assumptions, we feel, are very optimistic considering the advanced state of current technology.

The estimated 1990 factory door price of methanol produced in the 1980 built plant versus the improved 1990 design is 92 cents and $1.17 per gallon respectively, an advantage to the earlier plant of 27 percent.

Figure IV in the appendix is presented to show graphically the increase in capital cost for emerging energy technologies as they approach commercialization. Figures V and VI show the sensitivity of methanol cost to changes in plant efficiency and capital investment. These figures form the basis of the economics shown in table II.

We firmly believe if the United States is serious about developing large-scale, coal-based methanol capacity for fuel use, the sooner the program is initiated the better.

For reference, I would like to put into the record the accompanying appendix.

Thank you.

[Testimony resumes on p. 221.]

[The appendix referred to follows:]

## APPENDIX

Table I illustrates the percentage of methanol price of coal, capital and miscellaneous costs. Coal cost is varied from 0.29 to 1.75 $/MM Btu.

### TABLE I

**PER CENT OF METHANOL FACTORY DOOR PRICE OF CAPITAL, COAL AND MISCELLANEOUS COSTS**

| COAL COST, $/MMBTU | 0.29 | 0.58 | 1.16 | 1.75 |
|---|---|---|---|---|
| COAL | 7 | 14 | 24 | 31 |
| CAPITAL | 67 | 62 | 55 | 50 |
| OTHER COSTS | 26 | 24 | 21 | 19 |
| FACTORY DOOR METHANOL COST, $/GALLON | 0.54 | 0.58 | 0.66 | 0.75 |

CALCULATIONS BASIS: MID 1980 CAPITAL COSTS
100% EQUITY FINANCING
15% DCF
20 YEAR OPERATING LIFE
48% FEDERAL INCOME TAX

COAL: 8600 BTU/LB
METHANOL PRODUCTION: 5000 STPD

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## TABLE II

## DEFERRED CONSTRUCTION WITH TECHNOLOGY IMPROVEMENTS

Table II illustrates the inherent risk of resultant higher costs/gallon of methanol by deferring construction in order to utilize anticipated technology improvements versus initiation of a coal to methanol plant using currently available technology. The comparison is based on a plant constructed and on stream in 1980 versus a plant at the same location completed in 1990. The following assumptions are made:

COAL PRICE: Coal price for the 1980 plant @$20/ton will increase at 6% per year.

OPERATING COST: Operating costs will increase 7% per year.

CONSTRUCTION COSTS: Construction costs will increase at 8% per year.

PROCESS IMPROVEMENTS: Anticipated improvements in technology over the decade will allow a 1990 plant to operate with the following savings:

1) 10% improvement in the thermal efficiency
2) 10% saving in operating costs
3) 15% reduction in capital costs, 1980 dollars.

Basis for calculation:

Mid 1980 capital costs
100% equity financing
15% DCF
20 year operating life
48% Federal Income Tax
Coal: 1.16 $/MM Btu
Methanol Production: 5000 STPD

TABLE II (Cont'd.)

DEFERRED CONSTRUCTION WITH TECHNOLOGY IMPROVEMENTS

REQUIRED FACTORY DOOR PRICES

1980 Plant

| | 1980 | Δ | 1990 |
|---|---|---|---|
| Coal | 0.16 | 6%/yr | 0.28 |
| Capital | 0.36 | -- | 0.36 |
| Operating | 0.14 | 7%/yr | 0.28 |
| | 0.66 $/gal | | 0.92 $/gal |

1990 Plant

Coal $0.16\ (1.06)^{10}\ (.9) = 0.26$

Capital $0.36\ (1.08)^{10}\ (.85) = 0.66$

Operating $0.14\ (1.07)^{10}\ (.9) = 0.25$

1.17$/gal

| | Methanol Price, $/gal | |
|---|---|---|
| | 1980 | 1990 |
| 1980 Plant | 0.66 | 0.92 |
| 1990 Plant | -- | 1.17 |

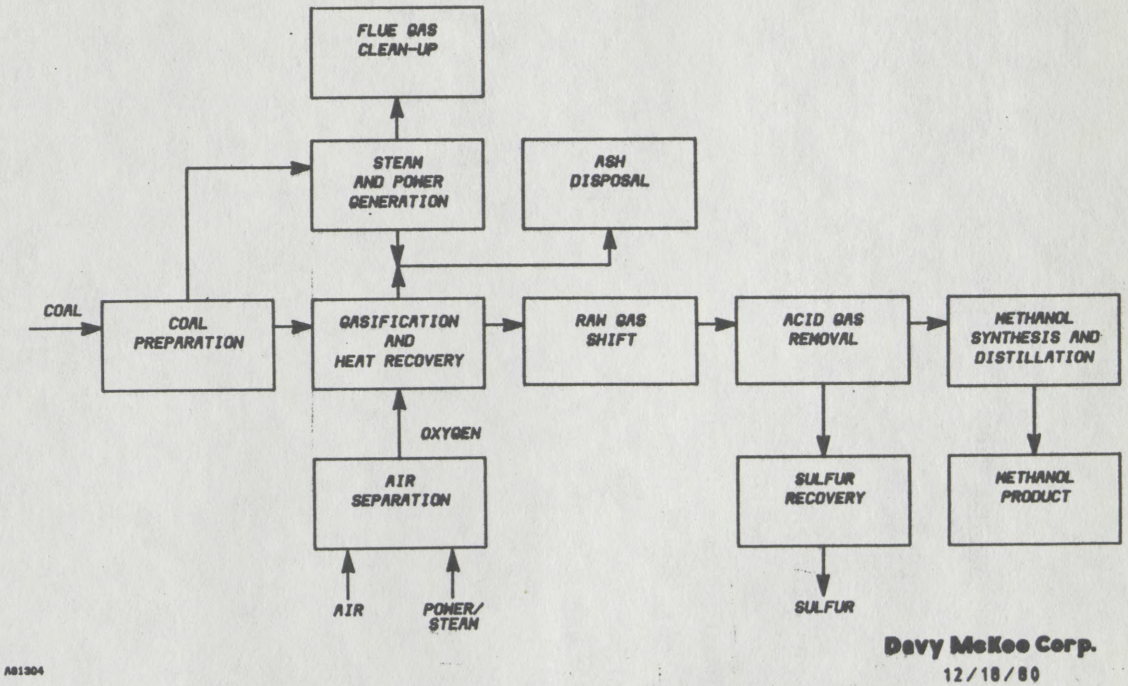
FIGURE I

SIMPLIFIED BLOCK FLOW DIAGRAM - COAL TO METHANOL PLANT

A simplified block flow diagram is presented in Figure I. This diagram represents the major processing steps in a coal to methanol plant. The diagram is valid for coal based methanol independent of the gasification process technologies utilized. For the various types of gasification systems and coal feedstocks, there will be different specifications for the processing units, i.e., coal preparation, unit operating conditions and capacities.

FIGURE I

SIMPLIFIED BLOCK FLOW DIAGRAM
OF A TYPICAL
COAL TO METHANOL PLANT

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## FIGURE II

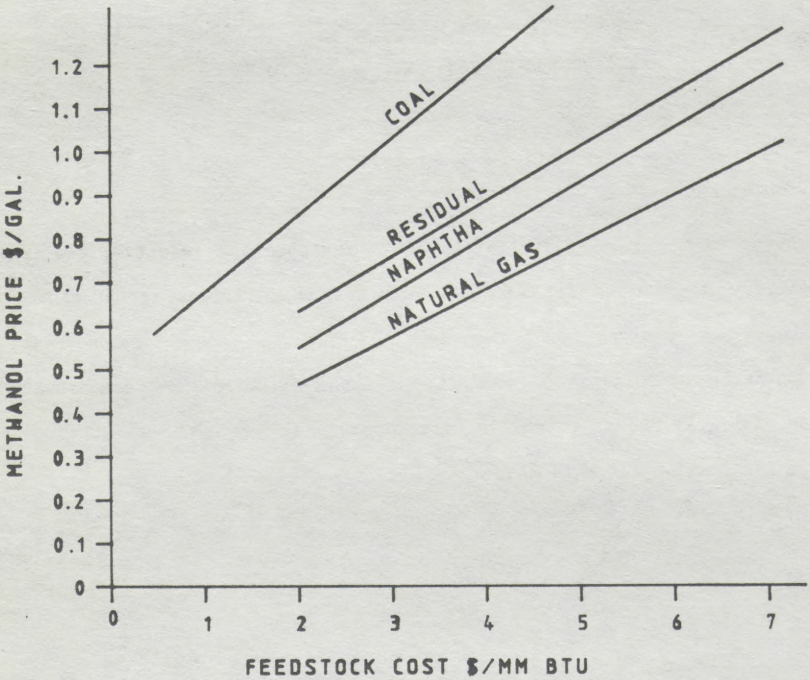
## REQUIRED FACTORY DOOR PRICE FOR METHANOL PRODUCED FROM VARIOUS FEEDSTOCKS

The purpose of this illustration is to indicate the relative, required factory door price for methanol produced from various feedstocks. A number of sources were compiled and adjusted to a common basis. Operating information, various internal studies on demonstrated technologies and an extensive private study (1) were the major sources of information for this figure.

(1) See List of References

FIGURE II

REQUIRED FACTORY DOOR PRICE FOR METHANOL
PRODUCED FROM VARIOUS FEEDSTOCKS




ECONOMIC PARAMETERS:

Mid 1980 Capital Costs
100% Equity Financing
15% DCF
20 Year Operating Life
48% Federal Income Tax Rate

FEEDSTOCK PARAMETERS:

| | | |
|---|---|---|
| Coal | : | 8600BTU/LB |
| Natural Gas | : | 980BTU/SCF |
| Naphtha | : | 5.0MMBTU/BBL |
| Residual | : | 6.25MMBTU/BBL |

Plant Output : 5000STPD

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FIGURE III

INVESTMENT COST PER UNIT OF CAPACITY VS PLANT SIZE

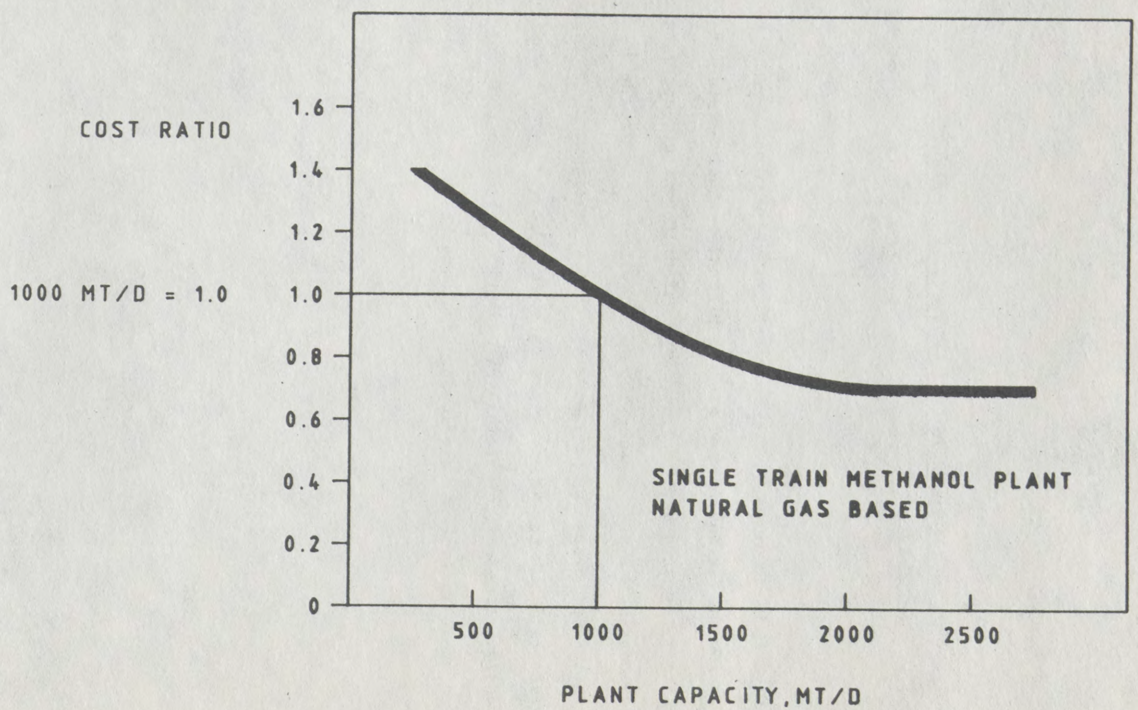


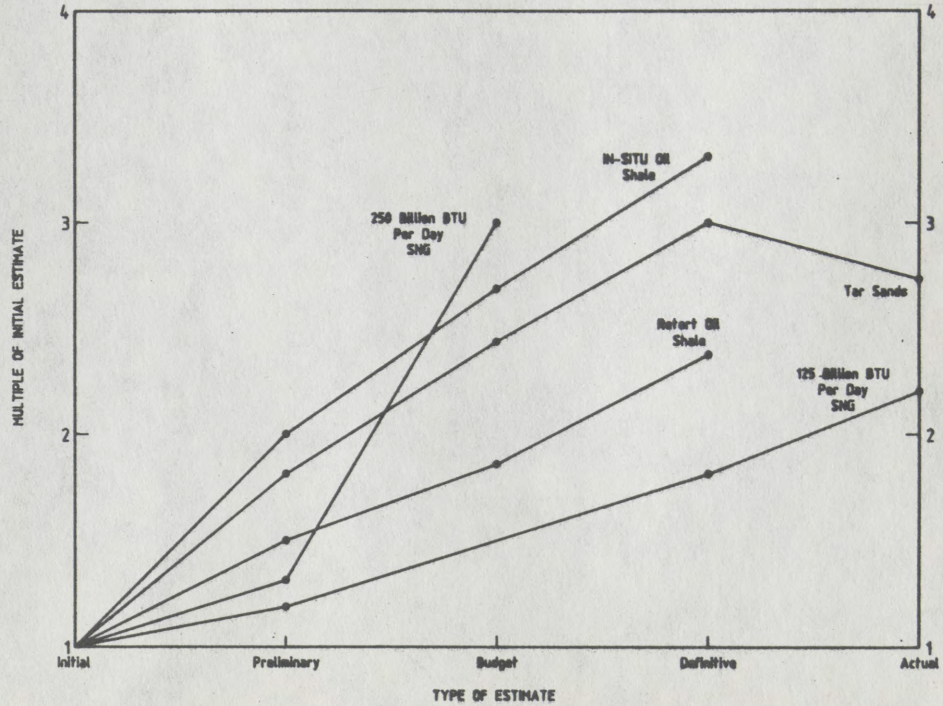
FIGURE IV

ENERGY PROJECTS COST GROWTH WITH COMMERCIALIZATION

Figure IV represents a history of cost estimates for the commercialization of various energy related process technologies. These estimates of varying accuracy were developed at different stages of bench, pilot, demonstration and commercial unit development. As can be seen, early estimates, based on preliminary process development or large scale-up factors, can escalate dramatically as projects reach the definitive design stage for commercial-scale units. This is a concern for accurate economic analysis of developing technologies.

## FIGURE IV

ENERGY PROJECTS COST GROWTH WITH COMMERCIALIZATION

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## FIGURE V and FIGURE VI

## 1980 COST OF METHANOL

### FIGURE V - COST VARIATION DUE TO CAPITAL COST ESTIMATE ACCURACY AT CONSTANT THERMAL EFFICIENCY

### FIGURE VI - COST VARIATION DUE TO CHANGE IN OVERALL PLANT THERMAL EFFICIENCY AT CONSTANT CAPITAL COST

Figures V and VI are graphs indicating the sensitivity of methanol prices in relation to process efficiency and capital investment for a coal to methanol plant of 5000 TPD capacity.

The cost of methanol has been plotted versus the cost of coal on Figure V. As parameters, the accuracy of the capital estimate has been shown as +25%, -10%.

On Figure VI, the cost of methanol has again been plotted versus the cost of coal, but this time overall plant efficiency has been plotted as the variable parameter.

It can be seen by comparing the two graphs that the accuracy of the capital estimate has a much more profound effect on the cost of methanol than does a change in overall plant thermal efficiency.

Figure VI shows that even significant increases in thermal efficiency, which are promised in new technologies, have relatively little effect on final methanol cost. A 10% increase in total plant efficiency, which will require major technological breakthroughs, offers only a 2-3% change in methanol factory door cost. Unfortunately, efficiency related breakthroughs normally result in significant increases in capital cost. This can negate improvements in efficiency when dealing with capital intensive systems, such as coal to methanol.

The above effects are combined with the effect of inflation in Table II.

FIGURE V

1980 COST OF METHANOL
COST VARIATION DUE TO CAPITAL COST
ESTIMATE ACCURACY AT
CONSTANT THERMAL EFFICIENCY

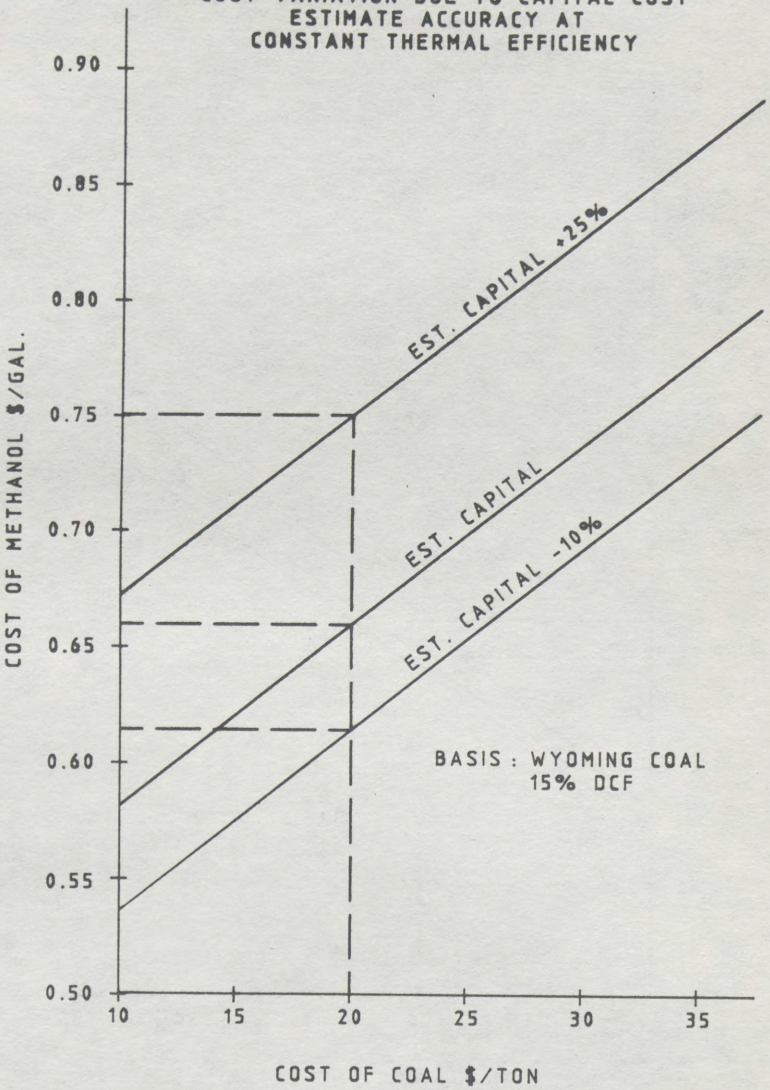


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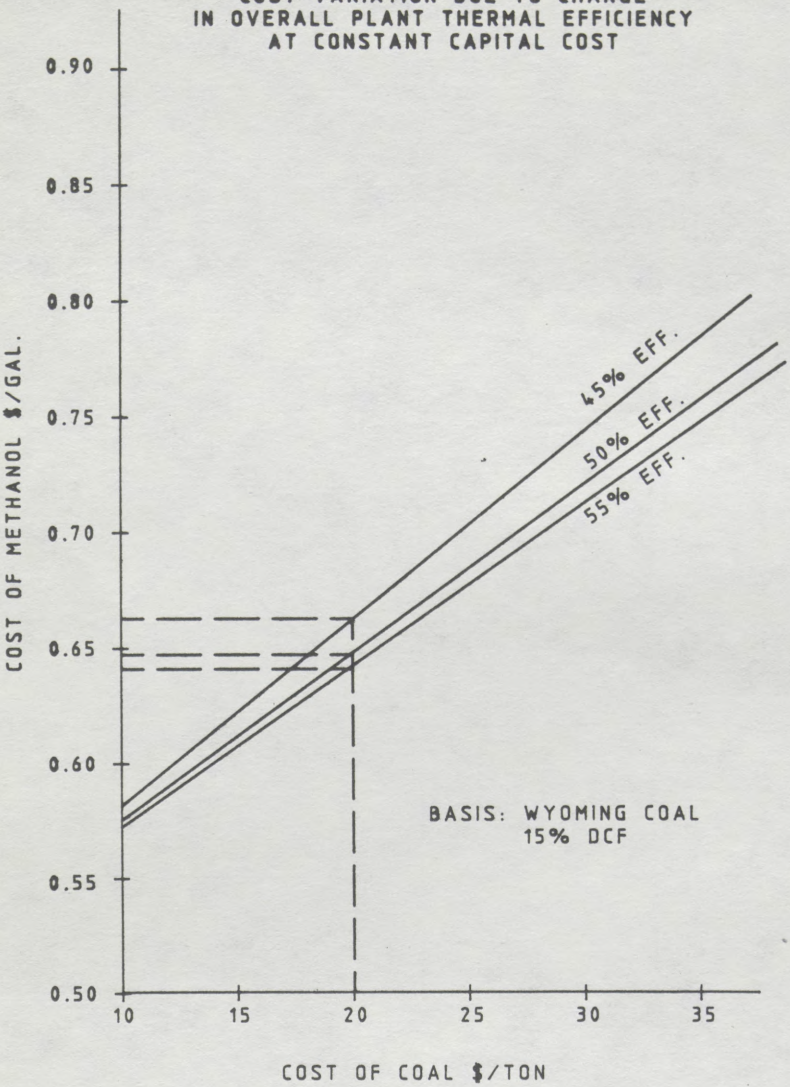
FIGURE VI

1980 COST OF METHANOL
COST VARIATION DUE TO CHANGE
IN OVERALL PLANT THERMAL EFFICIENCY
AT CONSTANT CAPITAL COST

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3. R. Arai - "Methanol from Coal Using Winkler Process and Low Pressure ICI Methanol Synthesis", October 1980, presented at the joint conference IMIQ and AIChE, Acapulco, Mexico.

4. Roger Williams Technical and Economic Services, Inc., and Charles A. Stokes Consulting Group - Private Study.

5. Dr. Arthur McGeorge - "Economic Feasibility Study, Fuel Grade Methanol from Coal", 1976, for Energy Research and Development Administration.

6. D. H. Eastland, "Methanol from Coal with Winkler Synthesis Gas", 1975, presented at the Second Annual International Conference Coal Gasification, Liquefaction, and Conversion to Electricity, University of Pittsburgh.


Mr. OTTINGER. The appendixes will appear in the record.

Thank you very much.

Let us have the testimony of Mr. Flint next.

## STATEMENT OF G. TORRENCE FLINT

Mr. FLINT. Thank you, Mr. Chairman.

We are also delighted to be here to provide testimony regarding the engineering aspects of coal-derived methanol. I am president of the Badger Energy, Inc. I have with me Mr. Dave Jones, vice president of technology of that company.

The Badger Co. is a designer, engineer, and constructor serving the petroleum, chemical, petrochemical, and energy-related industries. Headquartered in Cambridge, Mass., Badger maintains a worldwide staff of over 3,000 with offices in Tampa, Houston, The Hague, London, Paris, Tokyo, and other principal cities of the world. Badger's innovative approach to plant design for energy utilization and our experience in coal conversion and conservation of energy have led to the formation of Badger Energy, Inc., a wholly owned subsidiary of the Badger Co., to serve the energy field.

We are pleased to have the opportunity to present this summary of our views on coal-derived methanol for we believe that we can provide overall balanced information on this indirect liquefaction technology since our synthetic fuels experience includes both indirect and direct liquefaction technologies.

Badger's major direct liquefaction projects include the process design for the SRC-II demonstration plant proposed to be located in Morgantown, W. Va., and the construction management and erection of the H-Coal pilot plant located in Catlettsburg, Ky. Badger's major coal-derived projects include detailed conceptual designs of coal-to-methanol and coal-to-methanol-to-gasoline commercial plants performed for the U.S. Department of Energy.

In response to your request for this testimony, I would like to address the specific issues as set forth in your letter of December 5. First, the technical readiness of coal-to-methanol plants from an engineering standpoint.

The technical readiness of coal-to-methanol plants can best be addressed by looking at the technical readiness of each of the unit operations and processes that make up the plant. A typical list of unit operations for such a plant is as follows: Coal preparation, air separation, coal gasification, quench scrubbing, shift reaction, acid gas removal, sulfur removal, tail gas clean-up, and methanol synthesis.

Commercial units exist today for all of these process operations. The one qualification to this statement is the coal gasification unit. Although there are numerous coal gasifiers operating commercially around the world, for example, the Lurgi and Koppers-Totzek gasifiers, there are none operating in the United States. While the Lurgi gasifier operates at pressure, currently operating commercial gasifiers generally operate at relatively low or atmospheric pressure and are not considered to be the optimum choice for integration with a coal-to-methanol plant. It is certainly possible, however, to compress the gas from gasifiers for downstream processing into methanol. The effect is to add to the cost of the plant and ultimately to the cost of the final product.

Examples of the other unit operations are numerous. Coal preparation is routinely performed at any coal-fired utility. Air separation plants for producing oxygen are readily available from Air Products, Linde, and others. Quench scrubbing is also performed routinely following exothermic reactors in refinery, chemical, and petrochemical applications. Shift conversion is common in ammonia and natural gas-to-methanol plants. Proprietary processes such as Rectisol and Selexol are well proven in acid gas removal, as is the Claus process for sulfur recovery and the SCOT process in tail gas clean-up. Methanol synthesis is offered by Haldor-Topsoe, the catalyst, that is, ICI, and Lurgi, and is also well proven commercially.

In summary, it can be said that coal-to-methanol plants are and have been technically ready. The fact is that the necessary unit and process operations have not been put together to produce methanol from coal.

The second issue: Potential for further improvements in the coal-to-methanol process in terms of capital government, reliability, and energy efficiency. A coal-to-methanol process which incorporates a Lurgi or Koppers-Totzek gasifier can be considered to be ready from a technical viewpoint. The gasification system in the coal-to-methanol process is the most likely candidate for improvement with regard to capital cost, reliability, and energy efficiency.

High pressure/high temperature gasification processes such as Texaco, Shell-Koppers, and Saarberg/Otto, are currently under development and/or demonstration. Higher pressures and temperatures reduce the size of the equipment, eliminate or reduce compression costs, and reduce tars which cause downstream problems.

High pressure pilot gasifier units are operating in Western Europe and the U.S.A. in the range of 150 to 300 tons per day of coal. Texaco has designed 1,000-ton-per-day units expected to be on stream in the U.S.A. and Germany in 1983. Shell-Koppers is planning a 1,000-ton-per-day unit in The Netherlands to be followed by a 2,500-ton-per-day design.

Improvements in the gasification area may reduce capital cost and should increase reliability, and energy efficiency; however, it should be noted that the gasifier systems represent only 10 to 20 percent of the cost of the total plant. A small improvement in gasifier cost will not have a significant effect on the total plant or product cost. The price of the final product is most sensitive to the price of coal. Further improvements in cost, reliability, and efficiency may be expected as larger scale commercial units are integrated within the plant, as single trains are designed for higher throughput, and as engineers acquire operating experience.

## SCALAR ECONOMIES AND LIMITING FACTORS IN TERMS OF SIZE OF COAL-TO-METHANOL PLANTS

Badger completed a conceptual design for the U.S. Department of Energy for a coal-to-methanol full scale commercial plant, utilizing a southern Appalachian coal, and feeding 63,000 tons per day of coal to the gasifiers and producing 415,000 barrels per day of methanol. The parameters for the study were established by DOE to represent a baseline for comparison.

Because of the large scale of some of the units, the first commercial plant will not be of the capacity depicted by this conceptual design. Therefore, the impact of plant scale on product cost was evaluated. Based on plant capacity at one-half scale and one-third scale, methanol costs are increased by roughly 10 percent and 15 percent, respectively. If plant capacity were further reduced, say one-sixth scale and one-twelfth scale, methanol costs would increase dramatically by roughly 25 percent and 50 percent, respectively.

Plant capacities in the range of one-half to one-third of the conceptual design establish coal feed rates in the order of 20,000 to 30,000 tons per day of coal. Cost curves from an independent study indicate that the 20,000 to 30,000 tons per day range of plant size would take best advantage of potential economies of scale while generally utilizing commercially available equipment.

The erection and operation of such a plant of this capacity should be manageable within socioeconomic constraints and its impact on the infrastructure of given locales. This large-scale plant would also have the added advantage of using commercially-available equipment items, such as 2,000 tons per day air separation units. Also, the use of a large number of small gasifiers in a coal-to-methanol plant, although not desirable from a cost and operability point of view, is nevertheless technically feasible.

## RATIONALE FOR AND COSTS OF CONVERSION OF METHANOL TO GASOLINE.

The first phase of Badger's work under a DOE contract involved the conceptual design of a commercial facility to convert coal to methanol. The DOE contract was extended to include the conceptual design of a commercial facility to convert the methanol into gasoline via Mobil technology.

In general terms, the results of this work show that if methanol were priced at 50 cents per gallon, the price of gasoline would be slightly in excess of $1 per gallon. It should be pointed out that the heat content of 2 gallons of methanol is approximately equal to 1 gallon of gasoline.

As part of the rationale for converting methanol to gasoline, we must recognize that the Mobil process produces gasoline suitable for direct use in today's automotive engines. A second important consideration is that the infrastructure, including the national distribution system, is in place to market the gasoline product.

Although incremental costs for the conversion of methanol to gasoline can be estimated, the costs of fully utilizing methanol in the transportation market include costs which are not well known to us. Engine modifications, distribution system infrastructure, and water rejection in the methanol are just some of the potential high cost and problem areas which need to be addressed.

## INTERNATIONAL ACTIVITY RELATING TO THE MANUFACTURE OF METHANOL AS A SUBSTITUTE FOR PETROLEUM-BASED LIQUIDS

There is continual national and international activity related to improving and upgrading the manufacture of methanol, especially with regard to fuel grade methanol.

Historically, methanol has been produced under conditions which prevent the formation of higher alcohols, even though thermodynamically methanol is the least favored product of the reaction. This suppression of higher alcohols is important for chemical grade methanol but is not essential for the production of fuel grade.

Current activity with regard to fuel grade methanol concentrates on using a more reactive, less selective catalyst which will operate at a lower pressure. The result will be a product of higher molecular weight with less specificity to methanol, containing a range of oxygenates with an overall higher heat content. The capital and operating costs of producing this fuel grade methanol will thereby be reduced compared to the production of chemical grade methanol. The fuel grade will also show similar conversion to gasoline and produce less water as a by product.

Work is also being performed on improved catalyst configuration and liquified phase synthesis; however, this type of work is still developmental. There are continual and on-going efforts by the methanol process licensors to upgrade and improve the process thermal efficiency of their methanol units.

In summary, from an engineering standpoint coal-to-methanol is and has been technically ready. Significant potential exists for improvements in terms of capital cost, reliability and energy efficiency. Design and operating experience will lead to further economies of scale. It appears that coal-to-methanol-to-gasoline plants can be justified for the nearer term provided parallel efforts are undertaken to prepare the fuel grade methanol infrastructure for the longer term. There is on-going activity to improve the process of methanol synthesis and to separate the requirements of chemical grade methanol production from those of fuel grade.

In conclusion and of utmost importance I think to this committee however is the fact that given a site with all the appropriate construction permits a coal-to-methanol or a coal-to-gasoline plant can be built and operated based on present technology.

Thank you. I would be delighted to answer any questions that you may have.

Mr. OTTINGER. Thank you. Both you, Mr. Marten and you, Mr. Flint, have indicated the technical availability to produce methanol is presently here. What about in terms of quantities—if we wanted to go to a million gallons of methanol a day production where would the shortages be—a million barrels.

Mr. MARTEN. Well, there are I think as many views as there are people who have spoken on this. And this goes from coal mining capacity to coal transportation capacity, heavy vessel fabrication. I believe Mr. Hunt addressed himself to pipe valves, fittings, engineering capacity. I would have to say in any given circumstance, depending upon the particular economic level in the country, any one or all of these might prove to be constraints for the generation of a single massive facility or omega methanol industry if we wanted to use that term. I do not think it would be possible to predict which of the various limiting components would be active at any one given time. It might in fact be a combination of more than one.

Mr. OTTINGER. What kind of time frame are we talking about in terms of being able to build up that kind of capacity with the current constraints?

Mr. MARTEN. My cotestifier would probably agree. We are looking at, at least, 48 months now for a 5,000-ton-a-day gasification unit built in the United States—5,000 tons a day methanol product.

Mr. HUNT. That would be roughly about a 37,000-barrel a day plant.

Mr. MARTEN. Approximately, right. And this is assuming no environmental delays—the day the contract was signed all permits are in place—you are looking at about a 48-month engineering design, procurement and construction and start up effort.

Mr. OTTINGER. Would that be so if you were doing this on a large scale?

Mr. MARTEN. These are, as I pointed out before, multi-train plants. They would become sequenced. In other words you would not be able to get 50,000 tons a day of capacity on stream efficiently simultaneously, not saying you could not do it, but you would usually sequence these plants to come on stream depending on again whatever is the limiting constraint.

Mr. OTTINGER. Once you built the first plant, does it take 48 months to build the second plant?

Mr. MARTEN. Your engineering would be completed. It is a question then of your procurement and construction. I might point out the drag lines for coal today; you have a 5-year waiting period just for the drag line to get the coal mine going.

Mr. FLINT. I endorse his views. Our estimate may be a little bit longer than 48 months. I think we reflected that in the reports that we have submitted to the Department of Energy.

We have been involved in a large-scale synthetic fuels plants which has taken approximately 5 years from the start of our process design to the first drop of gasoline being produced. This is a plant that is significantly larger than 5,000 tons per day.

Mr. OTTINGER. Is that not a different proposition? That is the first of the kind technology. There are lots of technical problems that have to be solved along the way.

Mr. FLINT. Which are you referring to?

Mr. OTTINGER. The coal—

Mr. FLINT. I am referring to a plant outside the United States.

Mr. OTTINGER. For production of methanol?

Mr. FLINT. No production of synthetic fuels via the Fischer-Tropsch process—indirect which liquefication. There are basically two commercially proven coal-to-liquid fuels by the indirect route. And we are speaking about one today. And the other is through Fischer-Tropsch chemistry. This is being practiced as you know in South Africa. Their experience has been that it has taken about 5 years from the time that we started the design of the heart of that plant to the time it was actually in operation and turning out the first drop of gasoline. This is from the first of several phases or trains I should say that will be started up.

Mr. OTTINGER. Well, I understand there is a SASOL–2 and a SASOL–3 on the boards. Are they going to take 5 years each?

Mr. FLINT. SASOL–2 is taking 5 years.

Mr. JONES. I am David Jones, vice president of technology for Badger Engineering. SASOL–2, is a 40,000 ton-a-day coal fed facility. It is an indirect liquifaction facility and presents similar technical scheduling problems as a methanol facility. SASOL–2 was begun in 1975—the design of it was begun in 1975, the startup was begun early this year, approximately 5 years. SASOL–3, which is essentially a clone of SASOL–2, was started in 1979, the design of it, and will be started up at the end of next year. So you have gained about 1 year. In other words the first plant took about 5 years. An almost exact replica took about 4 years. Both of course, were done under very strong governmental support in that country.

Mr. OTTINGER. You think that is on the same scale with the kind of technical problems you would run into and supply problems, manufacturing equipment, transportation of coal and whatever?

Mr. JONES. Yes, sir.

Mr. OTTINGER. That you would have in a methanol plant?

Mr. JONES. It is a complete grassroots facility. A town was built for it, mines were dug for it.

Mr. OTTINGER. Mr. Marten.

Mr. MARTEN. The only comment I would have is that Fischer Tropsch technology tends to be quite a bit more complex, particularly in the number of processing steps and the fact that they are using a gasifier that produces liquids and other hydrocarbons that have to be treated to make it environmentally benign as opposed to a total gasification process—Texaco, Winkler, Westinghouse, K.T.

Mr. OTTINGER. Mr. Pefley.

Mr. PEFLEY. If I may, I would like to make a corrolary comment. I would like to speak as an educator and as a vice president of the American Society of Mechanical Engineers relative to this question you have raised. Our universities, through the 1970's, have fallen steadily in terms of their ability to cooperate and produce new technology. The graduate programs are in serious shape, and the faculties are leaving for want of adequate salaries. Our laboratories are becoming historic in the instrumentation and equipment sense. And to address this whole new technology, where we are talking about something in the order of a trillion dollars of GNP investment, we need to also recognize that the educational arena needs to be seriously invigorated.

Mr. OTTINGER. I agree with that. But I understand in the methanol technology, we are dealing not with new technology, but with established technology.

Mr. PEFLEY. I think what we are saying both in use and production we could do it, but we would like to be the leaders of the world in that sense, and that will not happen by this kind of logic.

Mr. OTTINGER. I was down in Brazil and smelled the same car or bus you did. It was their opinion whereas the ethanol produced aldehydes, I take it that causes the nice smell, it is relativley benign—if you use methanol you are likely to produce formaldehyde, and end up pickling your population. Is that a serious problem?

Mr. PEFLEY. I think it is serious. Although it is unregulated, the aldehydes are the one pollutants higher from alcohol fueled engines than the gasoline fueled engines. We have even made the suggestion to EPA if we are serious about the alcohols they ought to get involved in producing standards relative to the aldehydes. Now the catalysts handle the aldehydes very well, and they are not present in the Brazilian car. So that is a marked difference between the United States and the Brazilian situation.

Mr. OTTINGER. Our catalysts would clean up the aldehydes?

Mr. PEFLEY. Yes. I would make the point that in the early startup, when the engine is cold we see the high spike in aldehydes, before the catalyst starts working. And one of the major research efforts we invest in is to try to suppress that.

Mr. OTTINGER. Can you use a simpler catalyst than is required today to clean up our pollutants?

Mr. PEFLEY. It is our dream we can engineer an engine for alcohols that is so clean we can take the catalytic equipment off. We are not there yet. But that is what we would like to try and achieve.

Mr. OTTINGER. How would you remove the aldehydes in that situation?

Mr. PEFLEY. Well, the aldehydes are a partially combusted product. So if you get good clean combustion in the engine and the exhaust port area, you do not find the aldehydes present. For example, in a gas turbine, if you operate a gas turbine on pure methanol or ethanol even without catalytic equipment, you will find the aldehyde levels are completely tolerable.

Mr. OTTINGER. One thing in your statement. Your first recommendation I think was to require that our vehicles produced in the United States be compatible with a relatively low level of alcohol mixture. My understanding from the Brazilian experience is that they have gone in existing cars up to 20-percent ethyl alcohol without experiencing any problems with the operation of the car. Why would you need that kind of requirement?

Mr. PEFLEY. We have a much more tighly regulated scene in the United States. Some of our cars are lean burn. It is reported in the literature you can go to 5-percent methanol, 10-percent ethanol satisfactorily. But if you go to higher levels the leaning effect may cause driveability problems. So we think those percentages are completely compatible with the mode of operation of our U.S. cars. In Brazil, since they have no catalyst equipment, they typically run rich, and so you can go 10-, maybe even 15-percent methanol as was testified to here this morning. But that is not acceptable without significant modification—unless you use the electronic feedback control fuel injected engine. We mentioned one that would handle all percentages. But that is a more exotic fuel delivery system than a carburetor system.

Mr. OTTINGER. Mr. Hunt.

Mr. HUNT. Thank you, Mr. Chairman.

I would like to address a question to Mr. Marten.

In your analysis you indicated a specific type of coal was being used with respect to your process efficiencies, and indeed I think it was table I, you were using a coal that had roughly 8,600 Btu's.

Mr. MARTEN. Yes. That was lignite in that particular case.

Mr. HUNT. Your price per million Btu's seems to be rather high. Your $30 a ton—the $1.75—1 million Btu—do you know of any contracts that have gone for anywhere near that amount?

Mr. MARTEN. I have knowledge of many that have gone at the $20 ton rate today, including transportation. This is delivered cost. This is at the plant site from any location. This is not assuming that the plant is contiguous with the coal mine.

Mr. HUNT. Well, that would put an incremental penalty on it. Most of the arguments I have heard, or discussions I have read, with respect to this, if there is no water constraint problem, it seems wiser to build the plant right on top of the coal mine, not ship the water and ask what is in the coal, but ship the energy-dense final product. Would that cut the cost substantially in this case or not?

Mr. MARTEN. Well, if you look in the table I, we gave coal range cost ranges from $5 a ton to $30 a ton, a factor of six. And the methanol cost varied only from $0.54 to $0.75. In fact, at the $5 ton level, capital charges are nearly 70 percent of the total delivered cost of methanol.

Mr. HUNT. If you went to a much higher value coal, say strip mined Illinois Bituminous coal, would that affect the capital costs any or the cost of the product to any great extent?

Mr. MARTEN. Not significantly. Your tons of coal per ton of methanol would change approximately by two- or three-tenths of a ton. But the delivered cost of the product, we used 8,600 Btu a pound coal here, I do not think it would make much difference if it was 11,000 Btu a pound which would probably correspond to the $30 a ton coal.

Mr. HUNT. The coal type concept here—you have given quite a range from the standpoint of dollars per Btu?

Mr. MARTEN. Right.

Mr. HUNT. Would you address the issue, the problem of taking low-cost, high-sulfur coal as opposed to using compliance coal.

Mr. MARTEN. In the manufacture of methanol, sulfur must be totally removed from the synthesis gas produced so that the methanol catalyst will not be poisoned. Taking out the gross amounts of sulfur is relatively inexpensive. Since sulfur has to be removed down to let us say the tenth to two-tenths of a part per million level it is the removal from let us say 10 parts per million down to a tenth of a part per million that contributes the bulk of the cost of the sulfur removal. Therefore, the fact whether you started out with a feed derived from a 5-percent sulfur coal or a 1-percent sulfur coal, I would doubt that it would make 1 penny a gallon difference in the delivered cost of the methanol.

Mr. HUNT. Thus, if you had a surplus of high-sulfur coal that you could get at a reasonable price it would be cost effective to take advantage of it?

Mr. MARTEN. Definitely. In fact, if it was low moisture coal it might show a lower production cost than a very low sulfur, 30-percent moisture western lignite.

Mr. HUNT. OK. Your western lignite as I remember is rather high in water content?

Mr. MARTEN. Usually in the 20 to 30 percent range.

Mr. HUNT. So that coal involves an incremental cost relative to both its transportation and processing?

Mr. MARTEN. Processing it, the primary penalty.

Mr. HUNT. In your table I, you mention that you are using 100 percent equity and a 15-percent internal rate of return in your analytical methodology.

Mr. MARTEN. That is correct. In fact, we used the coal gasification commercial concept gas cost guidelines set up by C. F. Braun in January of 1976 in cooperation with DOE for all of our capital return calculations.

Mr. HUNT. I do not mean to press you, but it occurs to me that is rather a severe penalty, when most large processing plants of this nature are quite highly leveraged, particularly when it is a well proven process. Would something like 60 percent debt and the remaining 40 percent equity——

Mr. MARTEN. Well, this is true from an actual borrowing standpoint. When you are looking at rate of return it is usually treated as 100-percent equity because you have alternate uses for the same borrowing capacity. So from a return on investment standpoint, unless you were treating it as a utility, normal industrial financing is treated on a 100-percent equity basis, at least in my experience, for an evaluation standpoint.

Mr. HUNT. But not necessarily the actual financing of it.

Mr. MARTEN. That is correct.

Mr. HUNT. So just as a mechanism comparing one to another, it is handy to use the 100 percent?

Mr. MARTEN. Yes.

Mr. HUNT. But it does not necessarily reflect the real world costs.

Mr. MARTEN. No. In fact, if the synfuels industry were put under a utility blanket, there is no doubt that significant reductions in capital cost component of the methanol price would be achieved.

Mr. HUNT. I sometimes feel by going to loan guarantees we have gone well beyond even the charitable level of utility financing.

Mr. MARTEN. No comment.

Mr. HUNT. Mr. Flint, in the analysis that the Badger Corp. prepared for the Department of Energy, where they took the coal, methanol to gasoline and analytical route, I think you reported at that point that you were looking for a cost of 63,000 or 73,000 ton a day facility in 1990 roughly $1.09 a gallon.

Mr. FLINT. That is right.

Mr. HUNT. Correct me if I am wrong on this. I understand it takes, plus or minus some 5 or 10 percent, 2.44 gallons of methanol to manufacture 1 gallon of gasoline.

Mr. FLINT. That is right.

Mr. HUNT. And indeed it takes at the present time roughly 4 to 7 cents for that processing conversion. In other words, taking the 2.44 gallons and converting that to a single gallon of gasoline.

In this analysis you indicated on page 4 you were using a 6-percent discount rate relative to carrying that cost forward. It occurs to me that if one goes through the exercise of backing that down, that large plant in 1980 dollars, again using the initial technique that you used, today it would be capable of producing methanol for something in the 20 cents a gallon range. I recognize that is unrealistic because you cannot build such a plant. But from the standpoint of looking at today's market, that $1.09 seems to come back to roughly 20, 25 cents a gallon for methanol, in that neighborhood. Would that be consistent with the analytical procedure you have used?

Mr. FLINT. Mr. Hunt, I do not think so. Developing a scenario of the same amount of coal, producing the same amount of methanol as we reported in our DOE report, you would produce methanol, if that plant were in operation in 1987, we calculate, based on the facts and figures and the capital estimates in this report, that we would be producing methanol in 1987 for 45 cents a gallon or $7 per million Btu's. Now, if we were to take that methanol and convert it into gasoline during that same year, it would cost $9.25 per million Btu's. Now, this is based on a more realistic escalation of 9 percent per year, a debt to equity ratio of 65/35, and a 12-percent return on equity. In going from methanol to gasoline, you are adding about 30 percent to the cost. But if you want to relate the $1.10, or this $1.09 you referred to, it goes back to about a 45 cent per gallon methanol, not a 20 cent.

Mr. HUNT. Forty-five cent a gallon methanol in 1987.

Mr. FLINT. Right. Exactly. And if we rolled that back to today, you are probably close to it.

Mr. HUNT. Thank you.

Mr. Marten, do you believe that the lack of a market is one of the major constraints to the manufacture and operation of methanol plants today? Are we in a position where the absence of a good existing market is significantly constraining the development of this fuel?

Mr. MARTEN. Well, I think even aside from the transport fuel market, I think there would be a ready market in the utilities, particularly combined cycle plants. I live in Florida, and there are many combined cycle plants particularly in wintertime that are curtailed because they cannot get natural gas. So I think that for fuel grade methanol there would be an ample market for the initial installations irrespective of the development of the transport industry, which creates a super market, again, a megamarket that is nearly insatiable. I would say that there is a demand now in California and in Florida and other places of relatively clean environment that would utilize as boiler or turbine fuel if nothing else eventually all of the methanol that would be made today.

Mr. HUNT. Thank you very much.

Mr. Flint, just as an aside, the gentleman from Texaco this morning came up and told me that they have a history of correspondence within the last 4 or 5 months, with DOE whereby they are declaring, and DOE is accepting, the Texaco gasifier as a commercial unit today. That is, I believe, one of the pressurized gasifiers that you were saying would help and increase the efficiency of the operation of a coal-to-methanol plant.

Mr. FLINT. That is correct. This has been very key, where we are involved in the process design of the "SRC-2" project which is considering using the Texaco gasifier.

Mr. HUNT. For hydrogen generation?

Mr. FLINT. That is correct.

Mr. HUNT. Thank you very much. Thank you, Mr. Chairman.

Mr. OTTINGER. All right. I want to thank you all for your help to the committee. It has certainly been fascinating. We hope to work with you all in the future in tackling this promising technology.

Our next and last panel, Dr. John Gibbons, director of OTA, Mr. James M. Childress, executive director, National Alcohol Fuels Commission. And Mr. J. Dexter Peach, Director of Energy and Minerals Division of the General Accounting Office.

Gentlemen, we thank you for being with us today. We have had a lot of intriguing testimony today on the potential of methanol as an automotive fuel, the availability to produce methanol at very reasonable prices. We are very anxious to get your perspective on the work you have done in this field. If you are ready, I think we will call on you first, Jack. Thank you for coming down.

## STATEMENTS OF JOHN H. GIBBONS, DIRECTOR, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY THOMAS BULL, P.H. D., PROJECT DIRECTOR, ENERGY PROJECT; JAMES M. CHILDRESS, EXECUTIVE DIRECTOR, NATIONAL ALCOHOL FUELS COMMISSION; AND J. DEXTER PEACH, DIRECTOR, ENERGY AND MINERALS DIVISION, GENERAL ACCOUNTING OFFICE, ACCOMPANIED BY BOB ROBINSON, SUPERVISORY EVALUATOR, AND JAMES DUFFUS, SENIOR GROUP DIRECTOR

Mr. GIBBONS. Thank you. I have brought with me today Dr. Tom Bull, one of our several experts in this area.

I will summarize my testimony for you, Mr. Chairman, to try to provide time for discussion. [See p. 235.]

Mr. OTTINGER. The full statements of each of the witnesses will be included in full in the record today.

Mr. GIBBONS. There are a number of ways to reduce our dependence on foreign oil, without enduring significant penalties and indeed in many cases with economic advantage to the Nation. First of all there is considerable opportunity to increase energy efficiency and for switching fuel in stationary uses of liquids. More fuel efficient automobiles and other vehicles can certainly dramatically decrease the fuels that are required in the transportation sector.

And finally of course synthetic fuels can provide a direct substitute for oil.

At OTA we believe that increased efficiency of use and fuel switching of liquids away from stationary uses provides the least cost options at the present time and will likely be the biggest contributors to reduced oil consumption in the next decade. However——

Mr. Ottinger. Better translate that for me. What looks like the best option? I heard a lot of words. But I am not sure I know what they mean.

Mr. Gibbons. Our point is that in attacking the strategy of reduction of liquid imports to the country, and in facing the rising resources costs of liquid fuels, it is very important to keep attention not only to the sources of liquids in transportation, which is perhaps the highest use of liquids, but also the very substantial use of liquids in stationary sources, such as furnaces of homes, boilers, utility generators.

Mr. Ottinger. You say the stationary sources are likely to make a greater contribution than the vehicle sources?

Mr. Gibbons. In the coming decade we believe that they are as important if not more important than the automobile. That is not to say in the longer term.

Mr. Ottinger. Now I understand, anyway. I am not sure I agree. But I understand. Thank you.

Mr. Gibbons. And we believe, Mr. Chairman, as I think is inferred today, that the situation with respect to methanol and its uses looks particularly attractive in these strategies.

I have enclosed in my testimony a table labeled table I which gives estimates for the retail price—ignoring fuel taxes or subsidies—of various synthetic fuels as well as gasoline and diesel fuel from imported oil. We tried in this table to put various cost estimates on as equal a footing as possible so that the costs could be directly compared. For example, we use barrels per day of oil equivalent rather than barrels per day of oil and then in another case barrels per day of methanol.

Ethanol production from grain and sugar crops certainly is a commercially available technology today. However, ethanol is among the most expensive of the synfuels listed in table I, and its production in very large quantity will be limited by its inflationary impact on food prices.

Oil shale technology is now at the stage of commercial scale plant design and construction. But no full scale plants exist at the present time which can provide us real cost data. The product of oil from shale is principally a diesel or middle distillate type of fuel. But there are unresolved questions about the suitability of this fuel for certain end uses.

Methanol can be produced from coal with commercially available full scale technolgoy using Lurgi gasifiers. Gasifiers using more advanced technology have not yet been demonstrated on a commercial full scale basis.

Although OTA's analysis is not complete, we are in the process of an analysis of synthetic fuels, and it appears that methanol from coal is nearly competitive with gasoline in terms of the fuel cost.

Finally, methanol can be produced from wood with commercially available technology. This is by far the largest opportunity for producing liquid fuel from biomass, and it literally dwarfs the potential for producing ethanol from grains and sugar crops.

From a technical point of view, the best use of methanol fuel is as a high octane gasoline substitute and as a gas turbine fuel. It is possible to use methanol in a modified diesel engine, but this does not take advantage of methanol's high octane value.

Methanol can also be used as a jet fuel but of course its low energy density, that is the energy content in a given volume of the fuel, makes it poorly suited for aviation.

There is still some unresolved speculation about engine wear in methanol fueled vehicles used in cold weather. The conversion of existing cars to use methanol costs in the range of $500 to $800 per vehicle. Of course the conversion of existing cars results in a reduced driving range between fill-ups, and no increase in thermal efficiency of the engine which actually would accompany new cars designed to use methanol. New engines that are optimized for methanol could have about a 20-percent higher thermal efficiency or greater than a gasoline engine. This higher thermal efficiency would translate into improved miles per gallon and therefore in lower operating costs.

The added production cost for new cars to use methanol would be considerably less than the cost to retrofit existing cars. Using methanol as a gasoline substitute would in turn enable most refiners to increase their supply of middle distillates from a given barrel of crude oil because of the gasoline saved. Used as a gas turbine fuel, methanol displaces light distillate oil directly, of course.

Both positive and negative environmental effects will result from the substitution of methanol fuels for gasoline and diesel fuel. The production of methanol from coal or from biomass is likely to represent a net increased environmental cost compared to the alternatives of gasoline and diesel fuel from imported oil. These latter probably present fewer total environmental problems than a domestically produced methanol.

Of course, those differences may appear small when weighed against the economic and national security implications of reducing our imports.

Mr. OTTINGER. On that question, are you counting the pollutants that come from the burning of gasoline versus the——

Mr. GIBBONS. No, I am not. I will get to that in the next three sentences.

This environmental comparison includes the potential for oil-spills in the ocean and estuaries, and for emissions from the refining of gasoline and diesel fuel, balanced against the impacts of mining of the coal or harvesting of wood or grass and synthesizing the methanol.

Fortunately, it does seem likely that methanol synthesis will be one of the more environmentally manageable synthetic fuel processes when compared to, for example, oil shale processing.

Compared to gasoline and diesel fuel, methanol used in carefully designed spark ignition automobiles and trucks could very well represent an environmental benefit from the standpoint of air pollution. Although aldehyde emissions could increase, they can be adequately controlled, we believe, with catalysts or with careful engine design. Emissions of other reactive hydrocarbons, nitrogen oxides, and particulates, should all be lower for methanol compared to gasoline combustion.

In summary, Mr. Chairman, when compared to the present level of deregulated prices of petroleum based liquids, methanol is beginning to look attractive. It is a means of storing energy for long periods of time and in a form that is easily transportable. There is an existing market presently filled from natural gas resources. And there are several opportunities for incremental expansion into much larger markets including the transportation market. Opportunities exist for improving the cost of methanol from coal and from biomass, but potentially commercial process do exist already today. Some potential problems and uncertainties existing concerning the cost and the impact of fuel use. But until we have completed our analysis at OTA, it is premature by a few months for me to make specific comments on these issues or on suggested possible Federal actions which the Congress may want to consider.

Thank you.

[Testimony resumes on p. 242.]

[Mr. Gibbons' prepared statement follows:]

Testimony of John H. Gibbons
Director, Office of Technology Assessment

Before the Subcommittee on Energy and Power of the
House Committee on Interstate and Foreign Commerce
December 18, 1980

Thank you for the opportunity to testify today about methyl fuels. OTA has recently completed several assessments which touch upon various aspects of this subject. These include Energy from Biological Processes, An Assessment of Oil Shale Technologies, and The Direct Use of Coal. In addition, we are currently engaged in an assessment of Synthetic Fuels for Transportation, which was requested by the Senate Committee on Commerce, Science, and Transportation. In this study, which is targeted for completion in August, 1981, we are looking at all of the major synthetic fuel options and at technologies for increased automobile fuel efficiency. We hope this simultaneous examination of fuels and auto efficiency will shed light on the trade-offs between these two options. However, since that analysis is not complete, the information we will present today about coal liquids should be considered subject to change.

There are a number of ways to reduce U.S. dependence on foreign oil without enduring significant penalty - and indeed with economic advantage. First of all there is considerable opportunity for increased energy efficiency and fuel switching in stationary uses of oil. More fuel efficient automobiles and other vehicles can dramatically decrease the liquids needed in the transportation sector, and finally, synthetic fuels can provide a direct substitute for oil. Although increased efficiency of use and fuel switching of liquids away from stationary uses provide the least cost options at present and will be the biggest contributors to reduced oil consumption in the next 10 to 15 years all options need to be pursued.

For the specific case of methanol, several questions are relevant when considering it as a liquid fuel. First, how does methanol compare to other near term (e.g., in this decade) sources of liquid fuels in terms of cost and commercial availability? Second, what are the technical feasibility and benefits of using methanol to replace gasoline and middle distillates? Finally, what are the disadvantages and constraints on using methanol as a fuel and what Federal actions could encourage the production and adoption of fuel methanol?

Economic and Technical Comparison

Table I shows estimates for the retail price (ignoring fuel taxes or subsidies) of various synthetic fuels as well as gasoline and diesel fuel from imported oil. Direct coal liquids are not included because there are several unresolved technical questions about their production, refining, and use and because they are likely to be at best a minor supply of liquid fuels during the 1980's. For the other synthetic fuels, we tried to put the various cost estimates on as equal a footing as possible so that the costs could be directly compared. Construction delays and technical difficulties in the conversion facilities can raise any of these costs, however. For example, in OTA's Oil Shale report published last summer, it is shown that shale oil prices could be up to 20% higher than those used for Table 1 because of plausible delays.

Ethanol production from grains and sugar crops is a commercially available technology. It also appears to have the advantage of requiring the smallest capital investment per unit output of the several synfuels included. However, ethanol is among the most expensive of these synfuels and its production in large quantity will be limited by its inflationary impact on

Table I. Estimated Cost of Various Liquid Fuels (1980 Dollars)

| | Fuel | Estimated Retail[a)] Cost | | Plant Investment for $50,000 b/d oil equiv. |
|---|---|---|---|---|
| | | $/gal. | $/MMBTU | Billion $ |
| **High Octane Fuels** | | | | |
| Imported Oil ($32/bbl.) | gasoline[b)] | 1.20-1.35 | 9.70-10.80 | --- |
| Coal | methanol | 0.65-0.90 | 10.20-14.30 | 2.2-3.0 |
| Wood | methanol | 0.95-1.50 | 14.90-23.60 | 2.5 |
| Corn[c)] | ethanol | 1.35-1.75 | 15.80-20.60 | 1.5 |
| **Diesel Fuels** | | | | |
| Imported Oil ($32/bbl.) | diesel[d)] | 1.15-1.35 | 8.30- 9.70 | --- |
| Oil Shale | diesel[d)] | 1.60-2.30 | 11.50-16.40 | 2.0 |

a) Assumes a capital recovery factor of 30% per year at the synfuels plants and $0.15-0.20/gallon delivery and service station markup for high octane fuels and diesel from imported oil and $0.00-$0.10/gal. more for oil shale due to its distance from potential markets.

b) Assumes a gasoline to crude oil cost ratio of 1.4-1.5.

c) Assumes corn prices ranging from $2.50-4.00/bu.

d) Assumes a diesel to crude oil or diesel to upgraded shale oil price ratio of 1.3-1.5.

Source: "Methanol from Coal: An Adaptation from the Past," E.E. Bailey, Energy, Fall, 1979; OTA, "Energy from Biological Processes," Volume II, September, 1980; OTA, "An Assessment of Oil Shale Technologies, June 1980; Bob Reinstein, Energy Information Agency, U.S.D.O.E., Private Communication, November, 1980; Ed Bentz, E.J. Bentz Association, Private Communication, December, 1980.

food prices. OTA's analyses reported in "Energy from Biological Processes" indicate that consumer food bills could increase by several dollars for every gallon of ethanol produced if the total production significantly exceeds 2 billion gallons per year (less than 1% of current U.S. oil consumption).

Oil shale technology is now at the stage of commercial scale plant design and construction, but no full scale plants exist at present. The product of oil from shale is principally a diesel or middle distillate type fuel but there are unresolved questions about the suitability of this fuel for certain end uses. In order to transform this product into gasoline, it has to be refined extensively, which increases the cost and energy consumption of refining.

Most methanol in the U.S. is currently produced by steam reforming of natural gas to form a carbon monoxide-hydrogen mixture, from which the methanol is synthesized. With coal or wood as feedstock, the only difference is that the solid fuels are gasified to produce the synthesis gas mixture.

Methanol can be produced from coal with commercially available technology using Lurgi gasifiers. More advanced gasifiers (e.g., Westinghouse and Texaco) have not yet been demonstrated on a commercial scale. Though OTA's analysis is not completed, it appears that methanol from coal is nearly competitive with gasoline in terms of the fuel cost, assuming current petroleum and coal prices as well as present levels of construction costs.

Finally, methanol can be produced from wood with commercially available technology. This is by far the largest opportunity for producing liquid fuels from biomass, literally dwarfing the potential for producing ethanol from grains and sugar crops. With gasifier development and possibly mass-produced methanol plants, there appear to be good possibilities for reducing biomass methanol costs. However, no reliable estimates for the potential cost reduction are available at present.

Methanol as a Substitute for Petroleum

From a technical point of view, the best uses for methanol fuel are as a high octane gasoline substitute and as a gas turbine fuel. Methanol is the preferred fuel for the most sophisticated racing cars because of its high performance characteristics. It is possible to use methanol in modified diesel engines, but this use does not take advantage of methanol's high octane value. In fact, methanol's high octane is somewhat of a disadvantage when used in diesel engines. Methanol can also be used as a jet fuel, but its low energy density (energy content per unit weight or volume of fuel) makes it poorly suited for aviation. There is still some unresolved speculation about engine wear in methanol fueled vehicles when used in cold weather.

Over 100 gasoline-fueled automobiles in the U.S. have been converted to methanol. Most of these are test vehicles or vehicles in captive fleets. The conversion costs an estimated $500-$800 per vehicle.* The conversion of existing cars usually results in a reduced driving range between fill-ups (due to lower energy density of the fuel) and no increase in thermal efficiency, which would accompany new cars designed for methanol. The added cost of producing new automobiles designed and built for methanol would

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* J.L. Keller, et.al. "Methanol Fuel Modification for Highway Vehicle Use," Union Oil Co., final report to DOE, contract FY 76-04-3683, July 1978.

be less than the retrofit cost, but we do not have precise estimates at present. New engines optimized for methanol could have about 20% higher thermal efficiency (or greater) than gasoline engines due to methanol's high octane (which enables higher compression ratios and engine downsizing) and its lean burning characteristics (which can be used to reduce fuel consumption when less power is needed). The higher thermal efficiency translates to improved MPG and lower operating cost.

Using methanol as a gasoline substitute would enable most refiners to increase the supply of middle distillates from crude oil, in place of the gasoline saved. Used as a gas turbine fuel, methanol displaces light distillate oil directly. However, the total U.S. consumption of light distillate oil in stationary gas turbines is only about 130,000 bbl./day.

Both positive and negative environmental effects will result from substituting methanol fuels for gasoline and diesel fuels. The production of the methanol from coal or biomass is likely to represent a net increased enviornmental cost because the alternatives - gasoline and diesel fuel produced from imported oil - probably present fewer environmental problems. Of course, these effects may appear small when weighed against the economic and national security implications of reducing imports. The environmental comparison includes the potential for oil spills in the ocean and estuaries and emissions from refining gasoline and diesel fuel, balanced against the impacts of mining the coal, or harvesting the wood or grass, and synthesizing the methanol. Fortunately, it seems likely that methanol synthesis will be one of the more environmentally manageable synthetic fuels processes, when compared to oil shale for example.

Compared to gasoline and diesel fuel, methanol used in carefully-designed spark ignition automobiles and trucks could very well represent an environmental benefit from the standpoint of air pollution. Although aldehyde emissions could increase, they may be adequately controlled with catalysts. Emissions of other reactive hydrocarbons, nitrogen oxides, and particulates should be lower for methanol compared with gasoline combustion.

Finally, I should note that arguments have been made that the widespread distribution of methanol might pose new health dangers to the public. To my knowledge, no risk assessment of methanol vs. gasoline has been completed. Given the highly toxic nature of gasoline, I am not tempted to endorse such warnings without further study.

Constraints and Possible Federal Action

Synfuel and automobile producers are reluctant to make the necessary investments needed to produce or to use fuel methanol if they cannot be assured of a market for the product. The very large investment needed for a coal-to-methanol plant ($2-3 billion for a 50,000 b/d oil equivalent facility) have made banks reluctant to loan the money without loan guarantees or long term purchase agreements. Automobile manufacturers, hard pressed for capital to meet changes needed for gasoline driven automobiles, are unlikely to have the motivation or resources to venture into a new line of methanol fueled vehicles for the traditional auto market, unless uncertainty about gasoline availability increases their concern or that of their customers to the extent of exerting a market push toward methanol.

Nevertheless, the situation is not as inflexible as the above remarks might indicate. Currently, about 1.5 billion gallons per year of methanol (from natural gas) is used as a chemical feedstock; and as natural gas prices rise, methanol from coal can make inroads in this market. Captive fleets of vehicles (about 4% of automobiles are in fleets of 10 or more) and gas turbine users also could convert to methanol before a widespread fuel methanol supply infrastructure is established.

In summary, when compared to deregulated prices of petroleum-based liquids, methanol is beginning to look attractive. It is a means of storing energy for long periods of time and in a form that is easily transportable. There is an existing market presently filled from natural gas reserves and there are several opportunities for incremental expansion into much larger markets, including transportation. Opportunities exist for improving the cost of methanol from coal and biomass, but potentially commercial processes do exist today. Some potential problems and uncertainties exist concerning the cost and impact of fuel use but, until we have completed our analysis, it is premature for me to comment on these issues or suggest possible Federal actions, which the Congress may wish to consider.

Mr. OTTINGER. Thank you.

Next we will hear from Mr. Childress.

## STATEMENT OF JAMES M. CHILDRESS

Mr. CHILDRESS. Thank you, Mr. Chairman.

I am James Childress.

The National Alcohol Fuels Commission was created to advise the President and the Congress on the potential for alcohol fuels to displace imported petroleum, looking primarily at the transportation sector. We are in the final stages of completing our report.

My remarks today will be based upon that portion of Commission research dealing specifically with methanol and with its potential for penetration in the transportation market.

I will provide for the record a summary of the report [see p. 253] that is being prepared for the Commission by ICF, Inc. and upon which my testimony is based. I will also provide the entire report to the subcommittee staff.

Mr. OTTINGER. We will appreciate that.

Mr. CHILDRESS. My testimony will not cover the potential markets in stationary power generation or in petrochemicals, the Commission's view basically being that these will be penetrated as a result of economic forces.

As the price of oil- and gas-based fuels and petrochemicals rise over the decade, coal-based methanol should find a ready market. There will be no significant modifications necessary in processes or equipment that would require large capital outlays to accommodate coal-based methanol.

Let me also say in opening that I will not be addressing technical issues in any great degree. You have had technical matter laid out before you by previous witnesses far better than I could.

I would like to deal as much as possible with the public policy issues, very specifically with Federal policies that may need to be changed to encourage methanol production and use in this country.

As opposed to the petrochemical and utility sectors, the transportation sector is going to need some help in accepting methanol over the next decade. Existing gasoline or diesel powered vehicles must be modified, either in design or after production to run on pure methanol.

The existing petroleum distribution and marketing system would also have to be modified to accept methanol or other alcohols. These changes will require capital investment and some degree of assurance to the private sector that this investment will result in profit or at least not in loss.

I would like to address now several of the questions that the subcommittee has posed in calling these hearings.

First, as regards the readiness of the production processes, I will defer to the previous witnesses from Badger and from Davy McKee as far as the technical readiness. But I would point out that under the Energy Security Act, which established the Synthetic Fuels Corporation, there were two technical and marketing criteria that are to be applied in considering requests for funding for future projects.

One is the potential cost per barrel of synthetic fuel from a proposed project, and the other is the overall production potential of the technology, taking into account its potential for replication, its availability and the availability and geographic distribution of the feedstock.

On these two criteria, I think methanol comes out far ahead at this time as far as coal-based synthetic fuels. The Commission's view is that the U.S. Synfuels Corporation should aggressively pursue project funding for methanol.

I might add, in regard to Mr. Hunt's earlier comment about loans and loan guarantees, in my discussions with industry, they quite frankly find the purchase agreements as being much preferable to loans and loan guarantees in convincing their boards to invest billions of dollars in methanol plants.

The basic point of the ICF study that has been undertaken for the Commission was to look at the comparative advantage or disadvantage of the entire range of coal-based synthetic fuels.

I would refer you to table 1, which presents an abbreviated picture of comparative fuel costs in 1990 for methanol as a transportation fuel relative to other coal-based synthetic fuels. As you can see from the bottom line, methanol is a cost-competitive fuel, given certain assumptions.

The two most important factors in this are first, assemblyline production of pure methanol vehicles to cut the production costs and second, the access of the methanol to product pipelines which will significantly decrease methanol shipping costs.

If these two conditions are met, the fuel will be cost competitive. If it can be made cost competitive, methanol value——

Mr. OTTINGER. Let me stop you there, because I don't fully understand that.

Why do you have to ship the methanol in pipelines to make it economical? We get gasoline all over the country by truck.

Mr. CHILDRESS. Basically, the greater the volume that can be handled in shipping any bulk commodity, the lower cost per unit volume. One of the problems that potential methanol producers see in marketing is the fact that they would have to ship by barge or by tanker or by tank truck, which increases per unit cost, the per gallon cost, for shipping for methanol.

Mr. OTTINGER. There are existing pipelines that could transport that, are there not? There are oil pipelines; are they safe to transport methanol?

Mr. CHILDRESS. That is one of the unanswered questions. One key factor is that the volume from a large-scale methanol plant coming on line in the late 1980's, early 1990's, would probably be sufficient to have a dedicated pipeline——

Mr. OTTINGER. It is a horse of a different color, as I understand it. The methanol is a highly volatile, much more explosive item to transport around than oil is.

Mr. CHILDRESS. The primary problem from the perspective of pipeline companies is the corrosive nature of methanol and its tendency to pick up water. That would be the biggest problem as far as the pipelines are concerned. However, it hasn't been tested and it is an uncertainty——

Mr. OTTINGER. Can you ship methane around in gas pipelines without modification?

Mr. CHILDRESS. To my knowledge, yes; but methanol is chemically different from the petroleum products and doesn't present a problem in its transportation. It is one of the unknowns. As a matter of fact, it is probably going to be a larger problem than the first one that is producing the vehicles to consume pure alcohol.

Mr. OTTINGER. Just so I understand fully, we don't, at the present time, ship gasoline in pipelines; do we?

Mr. CHILDRESS. Yes; we do.

Mr. OTTINGER. To a substantial degree?

Mr. CHILDRESS. To my knowledge, I am not exactly sure of the details, but the explosive nature is not the problem from the point of view of the industry. It is primarily the corrosive problem from the methanol.

Mr. OTTINGER. We do that; all right. Do you have figures on that, Mr. Hunt?

Mr. HUNT. I can get them.

Mr. OTTINGER. All right. I am sorry to interrupt. I was under the impression the oil was shipped by pipeline and gasoline got shipped by truck.

Mr. CHILDRESS. If these two primary problems can be overcome, and I do not mean in any way to down play them, they are serious problems, methanol does have the potential of providing a large volume of high-quality automotive fuel to displace imported petroleum in the United States. However, this will not happen spontaneously.

There will be some public policy changes needed, some as a matter of fact within the purview of the Committee on Interstate and Foreign Commerce, to encourage greater production and use of methanol in vehicles in this country.

I would like to address a few of those factors at this time.

The primary constraint is the lack of existing markets for the product and for the vehicles. The market must be developed for both. Potential manufacturers of methanol in preparing feasibility and engineering studies are faced with marketing plans for the product which do not look promising under present conditions.

Let me remark on that point that an earlier witness did indicate there seemed to be large utility markets and petrochemical markets. However, in discussions with at least two representatives of industry, they would like a greater mix of markets, and a transportation market would be very attractive in making these projects economically feasible from that perspective.

Likewise, auto manufacturers have the technical capability of producing pure alcohol vehicles at a cost not greatly exceeding, and in fact perhaps equal to, that of gasoline vehicles, but do not see a large market because of the unavailability of the alcohol to power those vehicles.

Fuel and vehicle manufacturers need assurances of some sort that their heavy capital investments will result in marketable products. Because of this, some public sector support will be required to help provide captive vehicle fleets to introduce pure alcohol vehicles. That is, there would need to be Federal purchase guarantees to get these vehicles out into the marketplace, not just in Federal fleets but also private and State and local government fleets.

In addition, a number of Federal regulatory constraints could also impede the commercial introduction of fuel methanol and pure alcohol vehicles.

The Clean Air act places certain requirements on vehicle and fuel manufacturers that discourage the introduction and use of alternative fuels and the vehicles to use them. The engine certification and antitampering provisions of the Act, as well as strictures that discourage the introduction into commerce of nonpetroleum fuels are the most obvious impediments.

Pure alcohol vehicles can produce fewer regulated exhaust emissions than gasoline or diesel vehicles. It is therefore ironic that the above cited Clean Air Act requirements could place a heavy burden on producers of these alcohol vehicles and the fuels. The Clean Air Act would need to be amended to encourage introduction of alcohols and other nonpetroleum alternative fuels.

The amendments would not gut the Clean Air Act, but could provide the flexibility so that when alcohol fuel use and vehicle use are of a limited nature, the provisions for engine certification and for the waiver for nongasoline additives could be more flexible.

As alcohol vehicle and fuel use increased, they could then be put under the normal strictures of the Clean Air Act. In that way the introduction of pure alcohol vehicles could be encouraged with small environmental consequences—over the long run, as a matter of fact, I think with definite environmental benefits.

Mr. Ottinger. Let me ask something there: Is it the provisions of the act itself that provided this constraint or is it the EPA's interpretation and regulations which provided the constraint? I was under the impression it was the latter.

Mr. Childress. A case in point is the gasohol waiver which EPA has the administrative flexibility to allow. However, that administrative flexibility also would allow EPA to pull in that waiver at any given time. Now, gasohol is only one case in point. It is in a sense the first of our synthetic vehicle fuels.

In discussions with persons from Government and industry who are aware of the workings of EPA and the flexibility they have, the opinion is that a specified amendment to the Clean Air Act would provide the surety that would be needed.

Mr. Ottinger. That would be preferable. The EPA, as I understand it, this 10-vehicle exception granted to the United Parcel Service, is something that EPA invented. It is not something that is required by the act.

Mr. Childress. One final constraint I might add here, again, has to do with the corporate average fuel economy requirements which are intended to cut down on petroleum use by dictating increased auto fuel efficiency.

Presently the CAFE requirement for vehicle fuel economy are measured on a miles-per-gallon basis. Insofar as alcohol has fewer Btu's per volume of fuel than gasoline, the alcohols, as well as manufacturers of the alcohol vehicles are penalized. However, on a miles-per-million-Btu's basis alcohol is clearly ahead of gasoline. Methanol and ethanol are more efficient fuels than gasoline.

CAFE measurement procedures must be modified to permit full economy measurement on a Btu, rather than a volumetric, basis. This would allow, and in fact, encourage the introduction of alcohol and other nonpetroleum automotive fuels.

I might say in closing, that I was asked to comment on the potential for methanol to displace imported petroleum. The potential is obviously vast. Resources are vast; the technology is known. What I would encourage, in setting public policies to encourage methanol use, is that we not fall into the trap that we fell into with petroleum and natural gas—looking for one fuel that will solve all of our problems.

I think that diversity is called for in all energy policy, and as we explore synthetics especially, we should not foreclose future options for an immediate gain.

With that said, however, I think that what is known of methanol as a fuel, of its technologies and its uses, argues very strongly for an aggressive program to develop the vehicles and to get some of those methanol plants on line as quickly as posssible.

Thank you.

[Testimony resumes on p. 268.]

[Mr. Childress' prepared statement and summary report referred to follow:]

STATEMENT OF JAMES M. CHILDRESS,

EXECUTIVE DIRECTOR, NATIONAL ALCOHOL FUELS COMMISSION

Mr. Chairman, my name is James Childress and I am Executive Director of the U.S. National Alcohol Fuels Commission. On behalf of the Commission's Chairman, Senator Birch Bayh, and its Vice-Chairman, Representative Robert Roe, I wish to thank you for the opportunity to appear before you today.

The Commission, created to advise the President and the Congress on the potential for the use of alcohol fuels to reduce the need for imported petroleum, is completing its final report.

My remarks today are based on that part of Commission research dealing with methanol and its potential for penetration into the transportation fuel market. My testimony will not address the use of coal-based methanol in the petrochemical or utility/industrial power sectors. Methanol will likely penetrate these markets based primarily on economics: oil and natural gas-based fuels and chemicals will become more expensive than coal-based methanol which can be used in existing equipment and processes without capital-intensive modifications.

The transportation sector differs, however. Gasoline or diesel-powered vehicles must be modified -- in design or after production -- to run efficiently on pure methanol. The existing petroleum distribution and marketing system must be modified to accept methanol and other alcohols. These changes will require capital investment and some degree of assurance to the private sector that investment will result in profits.

o <u>The Readiness of the Production Processes</u>

Of all the proposed and potential synthetic fuel processes now available, those to produce methanol from coal are the most promising for early commercial operation to provide liquid transportation fuels. That is not to detract from other synthetic fuel processes. The goals of the Energy Security Act must be aggressively pursued by thoroughly evaluating all potential contributions that synthetic fuels can make to national energy production.

However, the gasification of coal and the reforming of the synthesis gas to make methanol are commercially proven as separate processes. What has not been done in the U.S. to any significant degree is to combine both processes into the same manufacturing facility. That marriage needs to take place on a priority basis to fully demonstrate the potential of the technology.

The Energy Security Act has established several criteria that the U.S. Synthetic Fuels Corporation must use in reviewing applications for financial assistance. Included among these are 1) potential cost per barrel of synthetic fuel from the proposed project; and 2) the overall production potential of the technology, taking into account the potential for its replication, the availability and geographic distribution of its feedstock, and the potential uses of the fuel produced. On these two critical criteria, methanol from coal technology is an attractive option to be aggressively pursued by the U.S. Synthetic Fuels Corporation.

o <u>Comparative Advantage of Fuel Methanol over other Synfuels</u>

Coal-based methanol can have a number of advantages as a vehicle fuel over other coal-based synthetic fuels.

However, methanol's competitive position with other coal-based synthetic fuels in the automotive market depends on two important factors: assembly line production to cut initial vehicle costs; and access to product pipelines to decrease methanol shipping costs. If these two conditions are met, the fuel will be cost competitive. (See Table 1) If it can be made cost competitive, methanol's value as an engine fuel -- from an environmental and a performance perspective -- is undisputed. A review of your witness list indicates that I need not elaborate on these items.

Methanol has the potential of providing a large volume of high quality automotive fuel to displace of imported petroleum in the United States. This will not happen spontaneously, however. Public policy changes, some within the purview of the Committee, on Interstate and Foreign Commerce, are needed.

o <u>Constraints on the Rapid Development of Methanol</u>

A number of factors could constrain the development of methanol as a motor fuel. The primary constraint is the lack of an existing market for the product and for pure alcohol vehicles -- a market must be developed for both. Potential methanol manufacturers preparing feasibility and engineering studies are faced with marketing plans for the product which do not look promising under present conditions. Likewise, auto manufacturers have the technical capability of producing pure alcohol vehicles (at a cost not greatly exceeding gasoline vehicles), but do not see a large market because of the unavailability of the alcohol to power the vehicles. Fuel and vehicle manufacturers must have some assurance that their heavy capital investments will result in marketable products.

Because of this, some public sector support will be required to help provide captive vehicle fleets to introduce pure alcohol vehicles.

A number of federal regulatory constraints could also impede the commercial introduction of fuel methanol and pure alcohol vehicles.

The Clean Air Act places certain requirements on vehicle and fuel manufacturers that discourage the introduction and use of alternative fuels and the vehicles to use them.

Engine certification, and anti-tampering provisions of the Clean Air Act, as well as strictures that discourage the introduction into commerce of non-petroleum fuels are the most obvious impediments. Pure alcohol vehicles can produce less regulated exhaust emissions than gasoline or diesel vehicles. It is therefore ironic that the above cited Clean Air Act requirements could place a heavy burden on the producers of these alcohol vehicles and fuels. The Clean Air Act would need to be amended to encourage introduction of alcohols and other non-petroleum alternatives fuels.

The Motor Vehicle Corporate Average Fuel Economy requirements, which are intended to cut down on petroleum use through increased auto fuel efficiency also discourage the introduction of alternative fuels. Presently CAFE measurements on vehicle fuel economy are measured on a miles-per-gallon basis. Insofar as alcohol has fewer BTU's per unit volume than does gasoline, alcohols (and the manufacturers of alcohol vehicles) are penalized.

However, on a miles per million BTU basis, methanol and all alcohols are more efficient fuels than gasoline. CAFE measurement procedures must be modified -- to permit fuel economy measurement on a BTU, rather than a volumetric basis. This will allow (and may, in fact, encourage) the introduction of alcohol and other non-petroleum automotive fuels.

o <u>The Potential for Coal Based-Methanol to Displace Imported Petroleum</u>

The U.S. consumes the equivalent of over 6 million barrels of oil a day in gasoline for highway transportation. That is roughly equal to the amount of petroleum we import. Whether it is feasible or desirable to replace that entire amount of gasoline with methanol is uncertain. Theoretically, the vast cellulose and coal resource base in the U.S. could provide sufficient raw materials to put the entire U.S. auto fleet on methanol by the year 2000. However, the enormity of that undertaking, and its economic costs could be prohibitive. Methanol can provide significant amounts of fuel for vehicles toward the end of the 1980's to permit us to diversify our motor vehicle fuel mix so that we are not entirely dependent upon petroleum-based fuels. The addition of a third pump at service stations--gasoline, diesel, <u>and</u> alcohol -- is a realistic and desirable alternative that must be fully explored.

Methanol is not a total solution to the problem of imported oil. The U.S. needs all available domestic energy it can muster -- increased production of traditional resources, increased conservation, and a major effort to begin producing synthetics. In the exploration of synthetics, a most attractive option is alcohol.

DRAFT

TABLE 1

FLEET AUTO COST COMPARISON IN 1990
FOR LARGE SCALE SYNFUEL DISTRIBUTION TO CHICAGO

| | Koppers Totzek Methanol Estimate | Badger Methanol Estimate | Texaco Methanol Estimate | BGC/LURGI Methanol Estimate | SRC-II Gasoline Estimate | EDS Gasoline Estimate | H-Coal Gasoline Estimate | Badger Mobil-M Estimate |
|---|---|---|---|---|---|---|---|---|
| Delivered Fuel Cost (in $1980 per MMBTU) | | | | | | | | |
| A. Plantgate Cost | 8.94 | 7.02 | 7.10 | 6.16 | 9.15 | 8.58 | 7.71 | 9.15 |
| B. Long Haul Transport | .15 | .15 | .15 | .15 | .08 | .08 | .08 | .08 |
| C. Local Distribution | 1.43 | 1.43 | 1.43 | 1.43 | .71 | .71 | .71 | .71 |
| D. Excise Taxes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E. Total | 10.52 | 8.60 | 8.68 | 7.74 | 9.94 | 9.37 | 8.50 | 9.94 |
| MMBtu Per Mile | .0045 | .0045 | .0045 | .0045 | .0056 | .0056 | .0056 | .0056 |
| Fuel Cost Per Mile (Line 1x2) | .0473 | .0387 | .0391 | .0348 | .0557 | .0525 | .0476 | .0557 |
| Fuel Cost Per Year | 1,089 | 890 | 898 | 801 | 1,280 | 1,207 | 1,095 | 1,280 |
| Annual Capital Costs ($) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Cost Per Year (Line 4+5) | 1,089 | 890 | 898 | 801 | 1,280 | 1,207 | 1,095 | 1,280 |

# METHANOL FROM COAL: PROSPECTS AND PERFORMANCE AS A FUEL AND AS A FEEDSTOCK

Prepared for
The National Alcohol Fuels Commission

## CHAPTER 1

## INTRODUCTION AND SUMMARY

The purpose of this report is to provide some background information for determining a role for methanol in a U.S. synfuel strategy. To that end and as instructed by the National Alcohol Fuels Commission, ICF compared methanol from coal with other, selected coal-based synthetic liquids as fuels for automobiles and electric utilities. In addition, methanol from coal is considered as a substitute for the methanol from natural gas now used by the petrochemical industry.

In the first section of this chapter, the plantgate product cost estimates used throughout the report are presented and explained. Each of the next three sections consider one of the energy uses studied herein: automobile fuels; fuels for electric utilities; and petrochemical feedstocks. A final section in this chapter outlines the remainder of the report.

### PRODUCT COST ESTIMATES

This report compares costs of synthetic fuels over the entire fuel cycle, but the first step was to estimate the cost of producing the selected synthetic fuels. Several estimates of product costs were developed for five liquid fuels derived from coal: methanol; gasoline from methanol with the Mobil-M process; and the gasoline, distillate, or residual oil made with direct liquefaction technologies. Except for the methanol estimate marked Koppers-Totzek, all of the estimates involve second-generation technologies. That is, technologies which have not yet been demonstrated on a commercial scale.

Table 1-1 displays the product cost estimates in terms of 1980 dollars per million Btu (MMBtu). The range of estimates in 1990 are as follows:

- Methanol - about $6 to $9 per MMBtu. Excluding the only first-generation technology, Koppers-Totzek, the range is about $6 to $7 per MMBtu.

- Direct Liquefaction Gasoline - the range is about $8 to $9 per MMBtu.

- Mobil-M Gasoline - the single relevant estimate is about $9 per MMBtu.

- Direct Liquefaction Distillate or Residual Oil - $6 to $7 per MMBtu.

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Notice that two numbers are listed for all the direct liquefaction technologies. The top number is the total product cost estimate while the bracketed number is the refining cost embodied in the total.

TABLE 1-1

PRODUCT COST ESTIMATES a/
(in $1980 per Million Btu)

| Technology/Estimate | Year Construction Completed 1990 | 1995 | 2000 | 2010 |
|---|---|---|---|---|
| Methanol | | | | |
| Koppers-Totzek | 8.94 | 9.62 | 10.36 | 12.06 |
| Badger | 7.02 | 7.52 | 8.09 | 9.33 |
| Texaco | 7.10 | 7.62 | 8.19 | 9.50 |
| BGC/LURGI | 6.16 | 6.61 | 7.10 | 8.20 |
| Direct Liquefaction-Gasoline b/ | | | | |
| SRC-II | 9.15 | 10.17 | 11.12 | 13.09 |
| | (2.23) | (2.74) | (3.11) | (3.78) |
| EDS | 8.58 | 9.43 | 10.26 | 11.97 |
| | (1.72) | (2.09) | (2.37) | (2.85) |
| H-COAL | 7.71 | 8.41 | 9.16 | 10.69 |
| | (1.36) | (1.58) | (1.82) | (2.17) |
| Mobil M | | | | |
| Badger | 9.15 | 9.81 | 10.54 | 12.19 |
| Direct Liquefaction-Distillate, Resid b/ | | | | |
| SRC-II-RESID | 7.04 | 7.83 | 8.56 | 10.08 |
| | (1.72) | (2.11) | (2.40) | (2.91) |
| EDS-RESID | 6.60 | 7.26 | 7.90 | 9.22 |
| | (1.32) | (1.61) | (1.82) | (2.19) |
| H-COAL-RESID | 5.94 | 6.47 | 7.05 | 8.23 |
| | (1.05) | (1.22) | (1.40) | (1.67) |
| -DISTILLATE | 6.32 | 6.89 | 7.51 | 8.77 |
| | (1.12) | (1.30) | (1.50) | (1.78) |

a/ The report displays other cost estimates in Chapter 4. Shown here are the estimates used for all cost comparisons in Parts 3, 4, and 5. Some of the key assumptions, as detailed in chapter 2, are a 15 percent capital charge rate, no construction delays, and a 90 percent utilization rate.

b/ Numbers in brackets are the estimated refinery cost already embodied in the total product cost.

Since the prime motive for pursuing synfuels is to reduce crude oil imports, it is also useful to display these product cost estimates in terms of crude oil equivalents. Table 1-2 presents such estimates. It's very important to understand the notion of crude oil equivalent used here. The figures shown here are the costs per barrel of average crude oil that, by ICF estimates, would yield gasoline, distillate, or residual oil at the product costs shown in the previous table. For example, in Table 1-1 methanol with the Koppers-Totzek estimate has a product cost estimate of $8.94 per MMBtu in 1990. In Table 1-2, a crude oil cost of $40.52 is shown because crude oil at this price would have yielded gasoline at a price of $8.94 per MMBtu.

The range of estimates in 1990 is as follows:

- For methanol, the range is about $27 to $41 per barrel. Excluding the Koppers-Totzek estimate, the range is $27 to $32 per barrel.
- For direct liquefaction gasoline the range is $35 to $42 per barrel.
- For Mobil-M gasoline the single comparable estimate is $42 per barrel.
- For direct liquefaction distillate or residual oil, the range is again $35 to $42.

It is also essential to remember these are crude equivalents at the plantgate. That is, they do not take into account costs of delivering and using these synthetic fuels. Costs at these later stages of the fuel cycle are substantial and they can affect significantly the cost comparisons among these fuels. As will be seen, methanol's delivery charges can be double those of gasoline while its costs of use can be much lower than gasoline because of its superior fuel efficiency.

Finally, there is a fundamental difference between the indirect and direct liquefaction technologies that should be stated here because it causes considerable uncertainty when estimating product costs for direct liquefaction and because it could become a key criterion for choosing between these two broad classes of synthetic fuels. The difference is that the indirect processes yield a single principal product while the direct liquefaction processes, which are assumed to include refining, yield an array of products.

Uncertainty arises for product cost estimation when several products are produced because one cannot easily allocate total annual costs among them. In other words, there are common and joint costs; one piece of equipment can be used in the production of all the products (common costs) and in some cases, one piece of equipment produces the products simulatenously (joint costs). For this report, total annual costs have been allocated among the direct liquefaction products by assuming a fixed relationship among four product prices. In other words, with the direct liquefaction processes the total, annual cost is assumed to be recovered by selling four petroleum products at

TABLE 1-2

CRUDE OIL EQUIVALENT COSTS[a/]
(In $1980 Per Barrel)

| Technology/Estimate | Year Construction Completed | | | |
|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2010 |
| Methanol | | | | |
| Koppers-Totzek | 40.52 | 43.79 | 47.35 | 55.52 |
| Badger | 31.29 | 33.69 | 36.43 | 42.39 |
| Texaco | 31.67 | 34.17 | 36.91 | 43.21 |
| BGC/LURGI | 27.15 | 29.32 | 31.67 | 36.96 |
| Direct Liquefaction-Gasoline | | | | |
| SRC-II | 41.53 | 46.43 | 51.00 | 60.47 |
| EDS | 38.79 | 42.88 | 46.87 | 55.09 |
| H-Coal | 34.61 | 37.97 | 41.58 | 48.93 |
| Mobil-M | | | | |
| Badger | 41.53 | 44.70 | 48.21 | 56.14 |
| DIRECT LIQUEFACTION- | | | | |
| SRC II - RESID | 41.27 | 46.09 | 50.54 | 59.80 |
| EDS - RESID | 38.59 | 42.61 | 46.51 | 54.56 |
| H-COAL - RESID | 34.56 | 37.79 | 41.33 | 48.52 |
| DISTILLATE | 34.54 | 37.87 | 41.50 | 48.87 |

a/ These are estimates of the crude oil costs that would yield the product costs shown in Table 1-1.

prices which have a fixed relationship. Since this same problem of cost allocation occurs with the production of conventional petroleum products, the assumed price relationship represents ICF's estimate of the way crude oil and associated refining costs would be allocated across conventional gasoline, distillate, and residual oil.1/ While ICF's approach is judged to be best suited for this report, there are other allocation schemes which would alter significantly the product cost estimates.

With respect to a choice between the two classes of technologies, it seems that a decision on methanol's role in the nation's synfuel strategy is indeed closely tied to a decision on the desired split between indirect and direct liquefaction technologies. That broad decision depends, in turn, on the intended role for synthetic fuels in the U.S. energy future. For example, if liquid synfuels are intended solely as a transportation fuel, it must be noted that the entire output from a methanol or a Mobil-M plant could, if demand warrants, be used for automobiles. In contrast, only a portion of the product yield from the direct processes is gasoline; Table 1-3 displays the assumed yields of the three direct liquefaction technologies studies herein.

TABLE 1-3

PRODUCT YIELDS FOR
DIRECT LIQUEFACTION TECHNOLOGIES
WITH REFINING
(barrels per stream day)

| | SRC-II | EDS | H-Coal |
|---|---|---|---|
| Gasoline | 8,963 | 18,511 | 15,070 |
| Distillate | - | - | 19,436 |
| Resid | 41,024 | 27,001 | 10,689 |
| LPG | 4,500 | 6,690 | 6,506 |

Product mix is, of course, a matter of a choice. The distillate and residual oil could, for example, be more severely refined and thereby, made suitable for gasoline blends; product costs would increase, however, with the considerably increased refining expense. But the central point remains. The indirect liquefaction technologies studied here yield a single primary product intended as a transportation fuel while the direct liquefaction processes yield a full product slate. If a full range of synthetic liquids is sought, perhaps it is appropriate to view the indirect and direct technologies as complementary rather than competitive. Products from the indirect, with some help from the direct, would serve as transportation fuels while the direct would serve primarily other important energy users.

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1/ The assumed price relationship is as follows: Distillate's price is 82 percent of the estimated gasoline price while the price for residual oil (and liquid petroleum gases) is 77 percent of the gasoline price.

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## SYNTHETIC FUELS FOR AUTOMOBILES

Methanol is most often proposed as a fuel for automobiles. This report first compares methanol and the synthetic gasolines in terms of technical and environmental performance and then a comparison is made in terms of the costs of owning and operating a methanol-powered and a synthetic gasoline-powered car. Finally, a rough projection is presented for fuel consumption by automobile fleets; fleets are considered the most likely users of methanol in the early stages of its development.

### Technical and Environmental Performance

The relationship between fuel and engine design is critical. Today's spark-ignition engines have been designed to maximize performance for gasoline blends with respect to fuel economy, environmental impact, vehicle operation costs and other factors. Since methanol has distinctly different physical and chemical characteristics when compared to conventional gasoline, certain modifications must be made by automobile manufacturers to current engine designs and fuel delivery systems.

Although all the problems facing the automobile manufacturer are solveable with currently available technologies, it is worth noting the two biggest--cold starts and lubricity difficulties.

- Cold Starts - Methanol engines are difficult to start in cold climates. Fuel modification, fuel heating and/or a dual fuel system are available techniques for overcoming this cold start problem.
- Lubricity - Today's lubrication oils have been developed primarily for hydrocarbon fuels and do not work as well with methanol. The development of new compatible oils and/or the use of corrosion inhibitors to reduce engine wear may be needed for methanol.

A methanol fueled spark-ignition engine can be designed which is superior to a gasoline fueled engine in terms of fuel economy and environmental performance.

With respect to energy efficiency, there is evidence that a methanol engine can be designed to get 15 to 25 percent more miles per Btu than a gasoline engine depending on the extent of engine modification. Equivalent increases in specific power are produced by the methanol engine as well.

In terms of environmental performance, methanol exhaust is generally cleaner than gasoline's.

- Nitrogen oxide emissions are reported to be lower (8% to 50% reductions are commonly reported by investigators).

- Carbon monixide emissions are as low, if not lower.
- No lead, sulfur and soot containing emissions are produced.
- A slight reduction in total hydrocarbons (by mass) can be achieved via methanol use.
- Aldehydes emissions, primarily formaldehyde with methanol, increase, but can apparently be held down to acceptable levels with engine modification and/or an oxidation catalyst.
- Subsequent ozone formation from methanol exhaust is less than gasoline's. This suggests that methanol fueled cars could have a beneficial impact on urban atmospheres.

Cost Comparisons

Costs over the entire fuel cycle are compared for three alternative automobile fuels: methanol; gasoline from the direct liquefaction processes; and Mobil-M gasoline. These cost comparisons could be shown to vary for several reasons. The two most important variations explored here concern the extent or scale of methanol use and the methods of pricing retail service and setting excise taxes.

Also seen within this report is the variation in cost due to type of use. As requested by the National Alcohol Fuels Commission, the two classes of users studied here are termed fleet and non-fleet. For these auto cost comparisons, note that both classes of cars are assumed to meet and maintain the 1985 average fuel economy standard for new cars--27.5 miles per gallon, according to the EPA estimate, which is the equivalent of about 22.5 miles per gallon on-the-road. The annual mileage of these two classes, however, is assumed to be quite different--23,000 miles per year for fleet cars and 12,000 miles for non-fleet cars. Fleet cars also differ here because they are assumed to avoid retail costs and excise taxes.

When examining methanol, the most important cost variation is caused by the extent or scale of methanol use. With limited use, several cost "penalties" may be associated with methanol. In this analyses, the cost penalties are assumed to be as follows:

- The cost of modifying a car for methanol use is $350. With large scale consumption, methanol-powered cars could be mass produced and the difference between constructing a methanol and a gasoline-powered car is assumed to be negligible.1/ (That cost of modification is assumed to be depreciated over three years with a straight-line method).

1/ Estimates based on information from the staff and Commissioners of the National Alcohol Fuels Commission.

- As explained before, methanol-powered cars are likely to be more fuel efficient than gasoline-powered cars. With small scale methanol use, that improvement is assumed to be 15 percent. When methanol-powered cars are mass produced, however, they can be optimized for this fuel and even greater improvements may be realized; the large scale case assumes a 25 percent advantage in fuel efficiency. (In both cases, the fuel efficiency improvement is measured in terms of miles per million Btu, not miles per gallon, and then put in terms of million Btu per mile for use in the cost comparison tables).

- In the small scale case, all fuels are assumed to be shipped by rail. With larger scale use, all the synfuels are assumed to take advantage of the lower rates of pipeline transport. Because of methanol's lower Btu content, about half that of gasoline, the change to pipeline transport lowers its cost more than the cost of the other synthetic fuels.

In the initial cost comparisons shown herein it was assumed that the charges for retailing and excise taxes are the same per gallon of methanol and synthetic gasoline. Since methanol has fewer Btu's per gallon than gasoline, these charges are higher per Btu of methanol.

To illustrate the uncertainty surrounding this topic, consider the difference between a gasoline and a methanol service station. Assume the stations would serve the same customers; that is, they would supply the fuel for the same number of miles of travel. Obviously, the methanol station would sell a greater number of gallons; with 25 percent superior fuel efficiency for methanol and 50 percent fewer Btu per gallon, sales in terms of gallons of methanol would be 60 percent higher.

The central question here is whether the service station's cost would rise commensurately. If the station's cost increase by 60 percent it is appropriate to set retailing cost equal per gallon. That is, it would be assumed new land, fuel tanks, and attendants would be added to handle the increased volume. For the cost comparisons this is termed high retail.

In contrast, one might assume the increased volume would be handled without added expense. Since the service station could spread its fixed costs over a greater number of gallons, the cost per gallon of methanol would be lower than for gasoline. For the cost comparisons, this is termed low retail.

Table 1-4 summarizes the many cost comparisons by showing the estimated differences in annual cost of a methanol-powered and a synthetic gasoline-powered car. For each situation, twelve comparisons are made in total because three estimates of production costs were used for methanol and four were used for synthetic gasoline (only the Koppers-Totzek estimates was excluded because it is a proven or first-generation system while all the others are second-generation.) It is the use of so many production costs estimates that cause the range shown in the Table. Notice these comparisons cover costs over the entire fuel cycle. That is, they include the cost of producing, delivering, and using these alternative auto fuels. (Bracketed numbers indicate a cost disadvantage for methanol.) For perspective on the significance of these differences, remember that the total annual cost of owning and operating a car will be several thousand dollars.

TABLE 1-4

METHANOL AND SYNTHETIC GASOLINE POWERED CARS:
RANGE OF DIFFERENCES IN
ANNUAL OPERATION COST
(dollar differences in annual cost per car)a/

| | 1990 | | 2000 | |
|---|---|---|---|---|
| | Fleet | Non-Fleet | Fleet | Non-Fleet |
| Small Scale, High Retail | (22) to 269 | (200) to (47) | 42 to 417 | NA b/ |
| Large Scale, High Retail | 197 to 479 | ( 4) to 143 | 271 to 635 | NA b/ |
| Small Scale, Low Retail | NA b/ | (68) to 84 | NA b/ | (35) to 161 |
| Large Scale, Low Retail | NA b/ | 102 to 249 | NA b/ | 140 to 331 |

a/ Estimates represent the difference in cost of using a methanol and a synthetic gasoline automobile. Bracketed numbers indicate a cost disadvantage for methanol.

b/ NA means these comparisons were not made.

The comparisons can be summarized as follows:

- With the small scale situation for fleet cars in 1990, methanol has a cost advantage in ten of the twelve cases and the advantage is up to $269 per car per year; in the other two cases the disadvantage is up to $22. By 2000, methanol has an advantage in all twelve cases which ranges from $42 to $417.
- With the large scale situation for fleet cars in 1990, methanol has a cost advantage in all twelve cases which ranges from $197 to $479 per car per year. By 2000 the range of advantage increases; the range is $271 to $635 per car per year.

- For non-fleet cars in 1990 assuming small scale distribution and high retail costs, methanol is at a cost disadvantage in all twelve cases ranging from $47 to $200.
- For non-fleet cars in 1990 assuming large scale distribution and high retail costs, methanol has a cost advantage in ten of twelve cases which can be as high as $143. In the other two cases, the disadvantage is negligible.
- Using what has been termed low retail costs for 1990, the cost comparisons for non-fleet uses change in favor of methanol. In the small scale cases, methanol now has a cost advantage in seven of the comparisons; the advantage can be up to $84. In the large scale cases, methanol has a cost advantage in all twelve cases and the range is $102 to $249 per car per year. By 2000, that range of advantage in large scale increases; it is $140 to $331.

Automotive Fleets and Fuel Use

It is likely that methanol will first be used as a fuel by automotive fleets. As illustrated above methanol use can be cheaper for this class of operators because they can avoid the cost of retail distribution and excise taxes. But more important is the possibility that some fleets will not be concerned with methanol's limited availability. That is, some fleet cars will be used in a narrow geographic area and can return for refueling to the fleet's central methanol storage area. Methanol use would not be precluded, as it might be for nonfleet or "family" cars, by the fact that it cannot be found in a number of service stations in most cities.

However, even for fleets which find an operating cost savings with methanol and, in addition, are not bothered by limited availability, there is at least one more disincentive for methanol use in the early stages of its development. The disincentive concerns the fact that many fleets consider resale value to be a primary criterion for an auto purchase and further, fleet cars are most often resold to used car dealers who in turn sell to the general public. If methanol is not available widely and non-fleet use is thereby precluded, resale value will fall to zero for many fleets when methanol-powered cars are used. This would raise considerably the cost estimates for methanol since the results presented in Table 1-4 assume the resale values are the same for methanol and gasoline powered cars. Inability to resell is an obvious and a very important disincentive to methanol use in automotive fleets.

Despite this important disincentive, automotive fleets are still the most likely first-round market for methanol. They are also a likely target for many other new auto fuels or technologies. For example, the federal government already has programs encouraging, through subsidies, the use of methane in cars as well as the introduction of electric vehicles and may mandate the use of gasohol in federal fleets.

Table 1-5 displays a projection of total fuel use by automotive fleets in terms of methanol consumption. A distinction is made in the table between two sizes of fleets--those with ten or more cars and those with 4 to 9 cars. The larger fleets are better targets for methanol use in the early stages of its development, but only a fraction of these might be suitable. For example, in 1979, 25 percent of the cars were in "lease" fleets; that is, the cars were purchased in mass, but then leased to individuals for unspecified uses. Another 45 percent of the cars were in business fleets and these may be likely candidates, but only limited information is available on their driving practices such as ability to refuel at a central location. The fleets for which methanol use clearly seems appropriate are those owned by state and local governments, utilities, and taxi operations. Even in these cases, which accounted for 20 percent of fleet cars in 1979, there would be exceptions.

TABLE 1-5

TOTAL FUEL USE BY FLEET CARS
IN TERMS OF METHANOL CONSUMPTION[a/]
(trillion Btu of methanol)

| Year | Fleets of 10 or More | Fleets of 4 to 9 | Total |
|---|---|---|---|
| 1985 | 1,048 | 462 | 1,510 |
| 1990 | 1,161 | 428 | 1,589 |
| 2000 | 1,443 | 428 | 1,871 |

a/ To translate to barrels of methanol remember there are 2.65 MMBtu per barrel. In contrast, there are 5.3 MMBtu per barrel of gasoline.

Source: ICF Incorporated

ELECTRIC UTILITIES

With respect to technical performance, only limited testing has been done with methanol by utilities. These tests, however, have shown that, with minor equipment modifications, methanol can perform on a par with oil and natural gas in combustion efficiency and power production capabilities. There can, however, be some problems which can be traced to the same physical and chemical properties as were the problems encountered with cars; corrosion of certain metals and the need to double the fuel flow rate are good examples.

As with automobiles, methanol's environmental performance in utility technologies can be superior to that of conventional fuels. Sulfur dioxide, particulates, and nitrogen oxides are the prime environmental concerns with utilities. As noted before, methanol combustion would not produce any sulfur dioxide or particulate emissions and $NO_x$ emissions could be very low.

It is assumed for the purposes of the cost comparisons in this report that methanol as well as the residual and distillate oil from direct liquefaction can be used without significant equipment modifications in both new and existing gas turbines, combined cycle facilities, and in conventional oil and gas-fired boilers. With this assumption a cost comparison among competing fuels is reduced to a simple comparison of delivered fuel prices; that is, equipment operation and maintenance costs will not vary by fuel type.

Table 1-6 summarizes the cost comparisons. The only distinction between the large and small scale cases is the means of transport; for small scale all fuels travel by rail, but in the large scale cases methanol and distillate use pipelines. The range of estimates is caused by using the range of plantgate costs shown earlier. (Again, the Koppers-Totzek estimate is excluded because it is the only first-generation technology.)

- For the small scale cases in 1990, methanol is at a fuel cost disadvantage in eleven of the twelve comparisons; that disadvantage could be up to $1.99 per MMBtu. By 2000 there is little change, methanol has an advantage in only one case.
- For the large scale cases in 1990, methanol has an advantage in only two of the cases. The disadvantage is up to $1.57 per MMBtu. By 2000, the situation does not change significantly, methanol still has an advantage in these two cases.

TABLE 1-6

METHANOL AND SYNTHETIC DISTILLATE AND RESIDUAL OIL: Differences in Delivered Fuel Cost a/ (differences in $ 1980 per MMBtu)

| | 1990 | 2000 |
|---|---|---|
| Small Scale | (1.99) to .05 | (1.97) to .63 |
| Large Scale | (1.57) to .47 | (1.55) to 1.05 |

a/ Estimates represent the difference in delivered fuel prices between methanol and synthetic distillate and residual oil. Bracketed numbers mean methanol is at a cost disadvantage.

In these comparisons then, the direct liquefaction technologies seem to have a cost advantage. The advantage could be lessened or eliminated, however, if the distillate or resid require further upgrading. Further tests are required to resolve this issue.

In the post-1990 period, the use of any liquid fuel in any significant quantities will probably be limited to daily and seasonal peak-load service in electric utilities. Liquid Fuel use will be limited to peak service because direct coal use seems to be the cheapest means of generating electricity in intermediate and base-load. For 1990, 2000, and 2010, demand for liquid fuels in daily peak-load service could amount to .34, .49, and .71 quadrillion Btu. Liquids may also be a low cost fuel for existing oil-fired units which serve seasonal peaks; that market could amount to about 1 quad or more in each of these years. Table 1-7 displays projected demand for liquid or gaseous fuels in daily and seasonal peak service.

TABLE 1-7

PROJECTIONS OF UTILITY DEMAND FOR
LIQUID FUELS IN PEAK-LOAD SERVICE
(in quadrillion Btu)

| Year | Daily Peak | Seasonal Peak | Total |
|---|---|---|---|
| 1990 | .341 | .894 | 1.236 |
| 1995 | .406 | .964 | 1.370 |
| 2000 | .490 | 1.039 | 1.529 |
| 2010 | .710 | 1.206 | 1.916 |

Some oil and gas is now used in both intermediate and base load service. That market should decline over time, however, as these units are retired, dropped to lower capacity factors, and replaced by coal or other fuels in 2000 and after. It is doubtful that methanol plants would be built to serve such a temporary market because direct coal use is the cheapest alternative.

Unlike most fuels, methanol use could actually be encouraged by very strict environmental rules because it emits lesser amounts of key utility pollutants. As example of such rules, consider the following:

- Acid Rain Control: Methanol's zero emissions of $SO_2$ and low emission of $NO_x$ may make it the preferred utility fuel for control of acid rain if very strict regulations are adopted by EPA and Congress. This is particularly true in the Northeast and Middle Atlantic areas.

- New Facilities in "Non-Attainment" Areas: Utilities that want to expand facilities in an area which has not attained the national standards for $SO_2$, TSP, or $NO_x$ may turn to methanol to avoid the need for costly "offsets" (i.e. emissions reductions in existing facilities).

- Tighter New Source Performance Standards: If the EPA were to declare tighter emission standards for $SO_2$ or $NO_x$, methanol could become the prime fossil-fuel for new powerplants. This potentially represents the largest utility market for methanol, and could conceivably replace coal if the standards were set low enough. There is little likelihood in the short-run of such a change in regulations especially since coal fuel systems can be made clean with flue gas desulfurization.

PETROCHEMICALS

Methanol, now produced from natural gas rather than coal, is an important chemical. With the impetus of rising natural gas prices and uncertain supply, the petrochemical industry is in search of a new raw material for methanol production. Although far from definitive, the cost comparisons presented here indicate coal-based methanol can be produced at a lower cost than that made from natural gas.

The key assumption for that comparison is that natural gas prices are deregulated in 1985 and, at that time, begin to track the oil prices assumed here. Since natural gas price is so key, Table 1-8 displays what can be termed breakeven natural gas prices. That is, the gas price at which coal-based methanol starts to be cheaper. As can be seen, the breakeven gas prices are far below the projected gas prices in each of the two years. Gas prices would have to be 30 to 40 percent lower than projected in 1990 in order to find gas-based methanol to be cheaper; by 2000 the gas prices would have to be 50 to 60 percent lower than projected.

The market for methanol as a chemical, rather than as a fuel for automobiles or utilities, might grow in the years 1990, 2000, and 2010 to .121, .208, .366 quadrillion Btu respectively.

The petrochemical market for methanol could be considerably larger than noted above if and when that industry decides to look for new and less expensive ways to manufacture the principal petrochemical building blocks. Some of the new ways to do this involve methanol. If the methanol-using routes prove cheaper and more reliable, methanol could become one of the foremost chemical intermediates and the demand for coal-based methanol could grow rapidly.

TABLE 1-8

NATURAL GAS PRICES NECESSARY TO MAKE
GAS-BASED METHANOL AND COAL-BASED METHANOL
EQUAL IN COST
($ 1980 per MMBtu)

| | Year 1990 | Year 2000 |
|---|---|---|
| Projected Gas Price | 5.39 | 8.45 |
| Breakeven Gas Prices | | |
| Badger Methanol | | |
| Rail Shipment | 4.34 | 4.69 |
| Pipeline | 3.34 | 3.68 |
| BGC-Lurgi Methanol | | |
| Rail Shipment | 3.80 | 4.05 |
| Pipeline | 2.79 | 3.05 |
| Texaco | | |
| Rail Shipment | 4.39 | 4.75 |
| Pipeline | 3.39 | 3.74 |
| Average | | |
| Rail Shipment | 4.18 | 4.50 |
| Pipeline | 3.17 | 3.49 |

## OUTLINE OF THE REPORT

The remainder of the report is outlined as follows.

- Part 2 contains chapters 2, 3, and 4. The purpose is to present and explain the product cost estimates used throughout the report. Key assumptions are listed and the effect of changing some of those assumptions is explored.

- Part 3 contains chapters 5, 6, 7 and 8. The purpose is to discuss methanol as an auto fuel. Chapter 6 deals with the technical and environmental performance of methanol-powered cars. Chapter 7 presents the cost comparisons of methanol and the synthetic gasolines. Finally, chapter 8 considers fleet car fuel use.

- Part 4 contains chapters 9, 10, 11, and 12. The topic is methanol use in electric utilities. Chapter 10 considers technical and environmental performance while chapter 11 presents the cost comparison. Projections of utility fuel use are dealt with in Chapter 12.

- Part 5 contains chapters 13, 14, 15 which all deal with methanol use in the petrochemical industry. Chapter 13 considers current methanol use. Chapter 14 shows the cost comparisons while chapter 15 discusses the possible level of demand for methanol as a chemical feedstock.

Mr. OTTINGER. Thank you very much.

We hear next from Mr. Peach from GAO.

STATEMENT OF J. DEXTER PEACH

Mr. PEACH. Thank you, Mr. Chairman.

We have done a considerable amount of work over the course of the last year looking at Federal programs dealing with alcohol fuels.

I have here with me on my left Bob Robinson, who has been the supervisory evaluator responsible for most of that work, and knows more about the technical details than I do. I have here also Mr. James Duffus, my senior group director, responsible for our work in the renewable energy area.

I have and will furnish copies of those reports for the record.[1]

[Testimony resumes on p. 281.]

[The following letter was received for the record:]

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[1] The reports referred to, "Potential of Ethanol as a Motor Vehicle Fuel, EMD-80-73, June 3, 1980" and "Conduct of DOE's Gasohol Study Group: Issues and Observations, EMD-80-128" may be obtained from the General Accounting Office or may be found in the subcommittee files.

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

ENERGY AND MINERALS
DIVISION

B-198431 July 22, 1980

The Honorable Charles W. Duncan, Jr.
The Secretary of Energy

Dear Mr. Secretary:

Subject: Concerns Over the Department of Energy's (DOE's) Program and Organization for Developing and Promoting the Use of Alcohol Fuels (EMD-80-88)

The General Accounting Office has recently completed a review of alcohol's potential for use as fuel for motor vehicles and the Federal efforts aimed at exploiting that potential. Our review resulted in a report to Senator Max Baucus entitled "Potential of Ethanol as a Motor Vehicle Fuel" (EMD-80-73, June 3, 1980), which he released on June 18, 1980, and which we recently sent to you under a separate cover letter. The report primarily discusses selected aspects of ethyl alcohol's (ethanol's) potential and the Federal and other efforts to assess that potential, but includes some of our observations relative to methyl alcohol's (methanol's) potential. Although the report contains no recommendations relative to ethanol's use as motor vehicle fuel, we do have a number of concerns which we believe warrant your immediate attention.

Our concerns are two-fold. First, DOE has yet to develop a comprehensive program for alcohol fuels which includes appropriate plans, goals, and strategies. Second, the effectiveness of DOE's recently created Office of Alcohol Fuels may be impaired due to limitations on its span of authority and responsibility and, relatedly, on the level to which the Office reports. While representing a significant step in the direction of achieving a comprehensive alcohol fuels program, we noted that the potential of methanol from coal is not being considered by this Office.

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In our opinion, these concerns are of sufficient magnitude to warrant your immediate attention. If left unresolved, they could lead to disparity in the Federal efforts to develop and exploit the use of these two alcohol fuels to their fullest potential.

The following sections provide a brief perspective on the potential of alcohol fuels which is needed for an understanding of the concerns raised during our review, as well as additional details on each specific area of concern. We are also providing a number of recommendations which you should implement to resolve these concerns.

## BRIEF PERSPECTIVE ON ALCOHOL FUELS' POTENTIAL

The Nation's dependence on imported oil and the disastrous economic and political consequences that have become evident from that dependence, have made it crucial for the Nation to find alternatives to oil-based fuels. The U.S. dependence on foreign oil has increased from 35 percent at the time of the crippling 1973-74 Arab oil embargo to a level of nearly 50 percent in 1979. The Nation's cost for this imported oil has grown from $7 billion to about $60 billion during this same period.

The potential for using alcohols--principally ethanol and methanol--as substitutes for oil-based fuels has received widespread attention in recent years. Numerous studies, research and development projects, and testing programs touching on various aspects of alcohol fuels' potential have been conducted at all levels of Government, as well as by private organizations. Some of these efforts were identified in our report to Senator Baucus.

Although alcohols can be used as fuel in a number of applications, such as to fuel turbines for generating electricity, their use as a substitute for conventionally produced gasoline in the transportation sector can have the greatest impact on reducing the Nation's oil consumption. In this connection, nearly 40 percent of the oil consumed by the United States each year is used to produce gasoline. Based on current U.S. consumption levels, about 110 billion gallons of gasoline are needed each year to power the Nation's motor vehicle fleet. Both ethanol and methanol can, to varying degrees, be substituted for gasoline thereby reducing the Nation's dependence on this oil-based fuel.

Accordingly, we looked at the potential of both fuels from the perspectives of their potential production levels and use in automobiles, the state-of-the-art of production technology, and potential cost competitiveness with gasoline. Overall, we found that alcohol fuels have vast potential to substitute for conventionally produced gasoline.

Production and use of alcohols for automobiles

Of the two alcohols, only ethanol is currently being produced and used as an automotive fuel in large quantities. By the end of 1979, ethanol was being used at an annual rate of nearly 80 million gallons in a blend commonly called "gasohol," consisting of 10 percent ethanol and 90 percent unleaded gasoline. At least 8 major oil companies, along with numerous independents, were marketing gasohol with generally positive results. As we pointed out in our recent report to Senator Baucus, it appears entirely feasible that, even considering constraints on the availability of feedstocks for producing ethanol, the Nation's entire vehicle fleet could be operating on gasohol by the year 2000.

Methanol's use as an automotive fuel has not been nearly as extensive. Most methanol produced today is made from natural gas and used in the chemical industry. Some oil companies have blended methanol with gasoline in proportions much less than 10 percent but its use in this capacity has been minimal. Methanol is also being used in small quantities as a feedstock for producing an automotive fuel additive known as methyl tertiary butyl ether.

Finally, the production of methanol as a feedstock for making synthetic gasoline via the so-called "Mobil process" has also been proposed and is receiving considerable attention. With this process, the production of significant quantities of gasoline could be started in the near-term and no problems, other than those that presently exist with conventionally produced gasoline, are expected to be encountered in its distribution and use. Methanol use, on the other hand, may require new distribution facilities and, because of unresolved issues related to methanol's toxicity, may necessitate development of new handling techniques to facilitate its safe use. While offering advantages over alcohol blends and straight alcohol use, converting methanol to gasoline and using it as fuel would be significantly less energy efficient than using methanol straight and would sacrifice methanol's low emissions characteristic. Thus, any decision-making process involving the commercialization of methanol will have to take into consideration the comparative advantages and disadvantages of methanol's use as a straight fuel or in blends with gasoline, versus its conversion into gasoline.

Although much larger quantities of ethanol are being produced today for fuel, methanol's ultimate production potential as an automotive fuel far exceeds that of ethanol. In this connection, vast quantities of methanol can be produced from coal which is in bountiful supply. Some studies have shown that existing coal reserves in this country, which are economically recoverable using current mining techniques, are sufficient to provide a methanol production capacity equivalent to fueling the Nation's entire motor vehicle fleet for about 100 years. Moreover, as we pointed out in our report to Senator Baucus, DOE has estimated that nearly 42 billion gallons of ethanol could be produced annually by the year 2000 with the use of cellulose feedstocks, such as trees, agricultural residues, and municipal solid waste. These same feedstocks, however, can potentially be used to produce nearly 155 billion gallons of methanol. Unlike ethanol then, which will probably be limited to the role of a valuable gasoline extender, methanol could eventually be produced in sufficient quantity to totally replace gasoline.

State-of-the-art of production technology

Unlike many other synthetic fuels options commonly being discussed, the technology to produce both ethanol and methanol is here today. Ethanol is now being produced from agricultural feedstocks using conventional fermentation-distillation techniques. DOE estimates that sufficient agricultural feedstocks can be made available using these techniques to annually produce about 11.5 billion gallons of ethanol by the year 2000. To produce additional quantities of ethanol, cellulose feedstocks would have to be used. Although the ethanol from cellulose technology is close at hand, additional improvements will be needed to make such production commercially feasible.

Methanol from coal technology has also been available for years. Prior to the availability of relatively inexpensive natural gas (which has subsequently faced periodic domestic supply shortages) as a methanol feedstock, France produced methanol from coal in the late 1940s, and in the mid-1950s the DuPont Chemical Company operated a methanol from coal plant in the United States. Advances which maximize the amount of methanol producible from a given volume of coal continue to be made. Nonetheless, industry officials told us that a commercial-sized methanol plant could, with existing technology, be in operation within 5 years.

The technology for producing methanol from cellulose feedstocks is similar to that for producing methanol from coal. Methanol produced from these feedstocks has a distinct advantage over methanol from coal in that the feedstocks are renewable. Also, methanol produced from these feedstocks would not entail the same degree of known environmental consequences that are inherent in producing methanol from coal. Economics, however, is a problem which most likely will have to be overcome before methanol from cellulose can be competitive with gasoline. This is largely attributed to the nature of the feedstock itself which is widely dispersed resulting in high costs for feedstock collection and transportation. According to a DOE official, a number of production processes are currently in the early stages of development which, when taking into consideration the rising price of gasoline, could lead to the economic production of methanol from cellulose in the near-term.

Cost competitiveness

As we pointed out in our report to Senator Baucus, the impact on the fuel consumer resulting from a nationwide gasohol program, as represented by the price at the service station pump, could be slight. On the other hand, with available technology, methanol's potential production costs indicate that the price of methanol could be significantly lower than ethanol's and, in fact, may be very competitive with gasoline's.

Considerable uncertainty exists over the potential production costs of methanol from coal plants since no domestic plants are operating today. However, the studies we reviewed indicated that methanol could be produced from coal for less than 50 cents a gallon at today's prices. This is about one-half the cost of gasoline and less than one-half the projected cost of ethanol. At this cost, methanol's price would roughly equal gasoline's on a constant energy basis since methanol contains only about one-half as much energy as the same volume of gasoline. Moreover, automobile engines designed for burning straight methanol are expected to achieve about 20 percent better fuel economy than existing gasoline engines and produce lower emissions, thus further improving methanol's competitive position relative to gasoline.

LACK OF COMPREHENSIVE PROGRAM FOR ALCOHOL FUELS

As noted in our report to Senator Baucus, DOE's policy on alcohol fuels is to help such fuels achieve their potential



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in the Nation's energy future. DOE, however, does not have a comprehensive program aimed at carrying out its policy. Operating within its broad policy, DOE is working towards achieving ethanol production goals of 500 million gallons annually by the end of 1981 and between 2 and 3 billion gallons annually by 1985. DOE has set no goals for the period beyond 1985, and no goals of any kind have been set for methanol production, even though methanol is recognized as having much more potential than ethanol for replacing gasoline and reducing the Nation's dependence on oil. Furthermore, DOE does not have a comprehensive program plan for ethanol and methanol with appropriate milestones and strategies, although efforts have been made to develop such a plan.

As discussed in our report to Senator Baucus, DOE established an alcohol fuels task force in December 1977. In its March 1978 report, the task force concluded that there was a need to take aggressive action to develop alcohol fuels, both ethanol and methanol, and recommended a program "* * *to provide the information considered essential for the introduction of alcohol fuels as one means for supplementing and eventually supplanting petroleum-derived fuels." The report was in the form of an alcohol fuels program plan and contained specific program goals and objectives and a proposed program structure to achieve those objectives. It also included generalized milestones for completion of the activities set forth. However, the findings and proposals were regarded by DOE as preliminary and the program plan was not implemented.

Subsequently, in July 1978, the Under Secretary of Energy established an Alcohol Fuels Policy Review to fully explore the potential of alcohol fuels as an alternative source of energy and to develop policy recommendations. The report of this review was issued in June 1979, and contains recommendations to stimulate the use of alcohol fuels from renewable resources. The report does not contain specific goals for alcohol fuels production nor recommendations for promoting the use of coal-derived methanol.

Both ethanol and methanol can have a significant role in resolving the Nation's liquid fuels shortage. To ensure that the potential role of each is effectively defined, and systematic efforts to reach such potential are undertaken, DOE needs a comprehensive alcohol fuels program. Such a program--addressing both ethanol and methanol in complementary fashion--should be developed around a program plan that sets forth appropriate goals, milestones, and strategies.

DOE has taken steps to improve its planning of alcohol fuels activities. Its recently created Office of Alcohol Fuels has been assigned responsibility for developing a program plan covering alcohols from biomass and directed at achieving production goals for ethanol. However, by not considering the potential of methanol from coal, this effort falls short of the comprehensive alcohol fuels program that is needed.

## LIMITATION ON THE POTENTIAL EFFECTIVENESS OF THE OFFICE OF ALCOHOL FUELS

As we noted in our report to Senator Baucus, Federal alcohol fuels activities have been fragmented. Within DOE, seven different organizational components have assumed roles in assessing and developing alcohol fuels potential. In addition, numerous other Federal agencies, including the Departments of Agriculture and Commerce, the Environmental Protection Agency, and the Tennessee Valley Authority, have initiated independent but related efforts. Until recently, there has been no mechanism to effectively coordinate and systematically organize these multiple efforts toward a common goal.

DOE's creation of a new Office of Alcohol Fuels in February 1980 was a significant and laudable step toward pulling together these previously fragmented activities. Among its mandated tasks, the Office was assigned the responsibility of coordinating all DOE policies, positions, and public statements regarding biomass and alcohol fuels, as well as working with other Federal agencies on alcohol fuels matters. In addition, the Office was tasked with developing a program plan to guide DOE's spending in fiscal years 1980 and 1981 related to alcohol fuels.

While we commend DOE for creating its Office of Alcohol Fuels, we are concerned that a major limitation on the Office's scope of work will hamper its ability to assemble a balanced and comprehensive alcohol fuels program. Within DOE, the Office has been given management authority to effectively coordinate efforts related to the development of ethanol, but efforts concerning methanol remain fragmented, with three different organizations sharing responsibility. The Office has been given responsibility for methanol produced from biomass. Methanol produced from coal, however, has been excluded from the Office's purview. That work remains split between the Assistant Secretary for Fossil Energy (research and development) and the Assistant Secretary for Resource Applications (market analysis and commercialization).

As indicated earlier, methanol produced from coal has vast potential. The availability of coal means it has potential for being produced in huge quantities and, using currently available technology, at a cost substantially below that of ethanol. By not considering the potential of methanol from coal in the Office of Alcohol Fuels, we are concerned that a comprehensive, balanced consideration of alcohol fuels, from the standpoints of both their development and commercialization, may not be achieved.

Within the realm of alcohol fuels, we believe methanol from coal activities would ideally be centralized within the Office of Alcohol Fuels. On the other hand, we recognize that a valid argument can be made for treating all coal-liquid technologies together so that their comparative potential can be measured and a comprehensive coal-use strategy developed. Still, we believe the development of a rational and comprehensive alcohol fuels program requires that consideration of methanol from coal be coordinated with alcohol fuels from other sources.

Accordingly, we believe that an acceptable alternative would be for DOE to establish an integrating mechanism that ensures methanol from coal be brought into the mainstream of alcohol fuels development and commercialization efforts so that a program of support for all alcohol fuels can be established based on their comparative potential. Such a mechanism could include creation of a standing coordinating committee, chaired by the Director of the Office of Alcohol Fuels, with members from organizational components having responsibility for those alcohol fuels activities that do not fall under the Office's purview.

Regardless of the mechanism used, however, for incorporating methanol from coal into the mainstream of alcohol fuels activities, the current requirement that the Office of Alcohol Fuels report to the Deputy Assistant Secretary for Solar Energy (within the Office of Assistant Secretary for Conservation and Solar Energy) would have to be reexamined. We believe the efforts to develop and commercialize alcohol fuels, through implementation of the type of comprehensive program needed, are sufficiently important to warrant that the Office be accorded a high level of visibility and management attention within the DOE organizational structure. This does not appear to exist under the current organizational alignment for the Office of Alcohol Fuels. Also, expansion of the Office's responsibilities to include methanol from coal technology would seem to render inappropriate the current requirement that the Office report to the Deputy Assistant Secretary for Solar Energy. The technology for producing methanol from coal does not involve solar energy and hence we are concerned that its incorporation into an office reporting to the Assistant Secretary for Solar Energy may not provide the technology with the visibility, importance, and attention that it might otherwise deserve. Under these circumstances, therefore, it would be preferable to require the Office of Alcohol Fuels to report, instead, directly to the Secretary of Energy or to the Under Secretary.

## CONCLUSIONS AND RECOMMENDATIONS

Solutions to the Nation's oil dependency problems are critically needed. The current level of imports is exacting a heavy penalty on the Nation's economy and can impact on its ability to conduct an objective foreign policy. In this context, the Nation can ill-afford further inaction and needs to begin making timely progress toward developing alternatives to the use of imported oil. Alcohol fuels offer a rare opportunity to provide the Nation with a partial solution that can be implemented with existing technology. Few other potential solutions can begin making so important a contribution without additional research and development.

Accordingly, we believe alcohol fuels merit the creation of a comprehensive program aimed at the rapid development and deployment of these fuels in the U.S. economy. In connection with creating such a program, we believe a comprehensive program plan with clear-cut goals and milestones is essential. Such a plan should provide definitive strategies to enable both ethanol and methanol to achieve their full potential and assume their appropriate roles in the Nation's fuel supply picture.

Further, we believe that DOE's activities related to ethanol and methanol should be balanced in consonance with their relative merit and potential. The presently existing fragmentation of these activities within DOE's organization, primarily with respect to methanol from coal, provides little assurance of achieving the desired balance. Consequently, a mechanism needs to be established to ensure that methanol from coal not be subjugated to a position of lesser urgency and importance vis-a-vis ethanol and methanol from biomass and thereby receive disparate treatment in commercialization activities.

We therefore recommend that you:

--Establish a comprehensive and balanced program for alcohol fuels and develop a definitive program plan setting forth appropriate commercialization goals, milestones, and strategies for both ethanol and methanol.

--Ensure that from an organizational standpoint, methanol from coal is brought into the mainstream of those activities aimed at promoting the development and use of alcohol fuels. This can be accomplished by establishing an integrating mechanism, such as a standing committee chaired by the Director of the Office of Alcohol Fuels and assigned responsibility for coordinating those alcohol fuels activities that currently do not come within the purview of that Office. Regardless of the integrating mechanism used, we believe the Office should be required to report directly to you or to the Under Secretary.

## IMPACT OF RECENT LEGISLATION

While our report was undergoing final processing, the Congress passed and the President signed into law the bill S. 932 known as the Energy Security Act (Public Law 96-294, June 30, 1980). This act contains a number of provisions which impact on this report and our recommendations. Most notable among these provisions are those contained in Title I, which establishes the U.S. Synthetic Fuels Corporation, and Title II which creates, and organizationally aligns within DOE, an Office of Alcohol Fuels.

The Corporation provided for under Title I is to be headed by a seven-member board of directors and is chartered for a 12-year life. The Corporation is authorized to issue financial assistance to synthetic fuels projects in a number of forms including loan guarantees, purchase agreements, and direct loans. In addition to providing such financial assistance, the Corporation is required to submit a comprehensive synthetic fuels development strategy within 4 years of the bill's enactment.

The synthetic fuels included among the Corporation's purview are coal, oil shale, and tar sands. As a coal-based synfuel, methanol from coal consequently falls within the Corporation's commercialization responsibilities.

The establishment of the Corporation therefore has a definite impact on our recommendations related to developing a comprehensive alcohol fuels program and ensuring that methanol from coal be integrated into the mainstream of alcohol fuels activities. Although the exact effects on DOE's existing organizational structure and activities are not known at this time, it is clear that a new entity with responsibilities related to methanol from coal has been created. However, for a variety of reasons, including the present uncertainty over when the Corporation will become fully operational, a provision of the act which authorizes DOE to assist the Corporation in carrying out its assigned functions, and the specific exclusion of fuels from biomass from the Corporation's purview, we believe our recommendations continue to have merit and should be acted upon as soon as possible.

Concerning the Corporation's uncertain operational date, it will probably take a number of months before the Corporation's directors are nominated and confirmed, an office established, and an operating program of action developed and implemented. In the interim, DOE can serve a valuable function by integrating its methanol from coal development and related activities into its overall alcohol fuels activities. In this context, we believe the adoption of our recommendations could improve the effectiveness of these activities and, ultimately, the transition of certain of these activities to the Corporation.

Even when the Corporation is fully operational, DOE will retain considerable responsibility for alcohol fuels development under the act. In this connection Section 172 of the act authorizes the Secretary of Energy to provide technical assistance to the Corporation, and directs the Corporation and the Secretary to exchange technical information relating to synthetic fuels. DOE's input into the Corporation's assistance programs and the development of the Corporation's synthetic fuels development strategy could be especially vital avenues of assistance. We believe the adoption of our recommendations could help DOE provide the best assistance possible. In this connection, by beginning now in the development of a comprehensive alcohol fuels program and strategy DOE can readily provide the Corporation with the technical assistance it may need in preparing an important part of its legislatively mandated strategy.

Finally, the Corporation is specifically excluded from any role in developing and commercializing fuels made from biomass. Lead responsibility for biomass-based alcohol fuels is retained by DOE's Office of Alcohol Fuels, which under the act is not authorized any role concerning methanol from coal. Divided responsibility for alcohol fuels development is therefore maintained. Consequently, our recommendations related to the development of a comprehensive and organizationally integrated alcohol fuels program continue to be equally, if not more, important with the introduction of the Corporation.

Our conclusions and recommendations related to the organizational alignment of DOE's Office of Alcohol Fuels are also affected. Section 220 of the act directs that the Office of Alcohol Fuels "shall be responsible directly to the Secretary of Energy." Thus, the Congress has taken what we believe to be a much needed action which on the surface appears to address our recommendation to this end.

There remains, however, some uncertainty over how this provision will be implemented. In this connection, DOE officials advised us that they are considering a number of options for implementing this provision. One option, for example, would have the Office of Alcohol Fuels report to the Secretary but continue to have its funding and administrative support provided through the Assistant Secretary for Conservation and Solar Energy. We are concerned that this option or possibly others under consideration could dilute the Office's authority and potentially hamper its effectiveness in developing and promoting the use of alcohol fuels. Consequently, we believe our recommendation in this area continues to have merit and we emphasize that in its implementation the Office's reporting relationship should be direct and not circumvented through an intermediary level within the DOE organization.

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As you know, section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the Senate Committee on Governmental Affairs and the House Committee on Government Operations not later than 60 days after the date of the report, and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report.

We appreciate the courtesy and cooperation extended to our staff during the review and would appreciate being informed on the actions you take on our recommendations.

Sincerely yours,

J. Dexter Peach
Director

Mr. OTTINGER. Very good.

Mr. PEACH. Our work basically shows alcohol fuels have a vast potential for replacing petroleum fuels, particularly in the automotive sector. Perhaps more important, unlike some other synthetic fuel options which do require a lot of R. & D. before commercialization can be expected, the technology to produce the alcohol fuels, both ethanol and methanol, is here today.

Ethanol is now making a contribution toward stretching available supplies, and methanol could eventually be produced in sufficient quantity to totally replace gasoline.

While most of my comments will deal with methanol because of its great potential, let me just make a few brief observations on ethanol.

There is a minimal but expanding use in a blend of 10-percent ethanol and 90-percent unleaded gasoline, commonly referred to as gasohol, which is now helping to stretch gasoline supplies.

The current selling price of ethanol is about $1.75 per gallon, but as new, more efficient distilleries come into use, the price could decline.

Because of feedstock constraints, however, we see ethanol's potential as being limited to a valuable gasoline extender or stretching the use in that area. This would appear particularly true unless we would develop cellulose based technology and move in that direction.

But when you begin to move into that direction, that is where you raise the question of methanol, because in the event of those types of feedstocks, the amount of methanol that could be produced is substantially more than the ethanol you would get.

Let me try to basically hit the highlights of what our work has indicated with respect to methanol.

First, taking the area of methanol production: Methanol is a synthetic fuel option which has a highly promising production potential. The production of methanol can take place with existing technology.

Water availability had at one point been cited as a problem for development of some types of synthetic fuels, particularly in the West. The work GAO has done in other areas has indicated that water availability may not be the obstacle to energy development in the West that many often thought it would be.

Mr. OTTINGER. What assumptions are there, on the assumption you go to methanol production?

Mr. PEACH. Obviously, if you deal with methanol production you are getting into methanol from coal. You would be looking potentially at the West as a development area because of the coal deposits there. But I particularly am referring to other work where we have tried to look specifically at the issue of whether water seems to be a big problem in terms of expanded energy use, particularly in those States thought to have some water problems.

Our work there, gathering a great deal of information, indicated there was not the degree of problem as you look into the 2000 year area and beyond. Basically, we found agreement from the Department of the Interior and others in terms of looking at the information we developed.

There have been other studies done since then.

Mr. OTTINGER. I would like to see the details of that. That assumes a substantial production of oil shale?

Mr. PEACH. Yes, sir. It assumes a substantial production of a variety of fuels. And, as a matter of fact, we are doing some followup work at GAO to that study, trying to look out beyond the year 2000 in terms of potential implications. But basically other studies done by the National Water Commission and by sources within Interior have been confirming the information we have developed.

Mr. OTTINGER. We would like to have that material.

Mr. PEACH. We have that report. I can also furnish a copy of that for the record[2] and, of course, can discuss further with the staff the implications of the further work we are doing now at this point.

Mr. PEACH. The available cost projections we have seen indicate methanol could be produced from coal for about 50 cents a gallon at today's prices. The cost of production from wood would probably be somewhat higher.

If you talk about uses in automotive fuel, it can be used, from the information we have seen, as an automotive fuel within existing technology itself as a blend in existing engines or straight in modified engines. The modifications necessary to use straight methanol can probably be accomplished on the assembly line at a relatively minor cost.

Further, consistent with other statements we have heard here today, methanol engines optimized to take advantage of methanol's high octane properties should operate more efficiently than existing gasoline engines, and because of these efficiency gains the use of methanol could result in lower overall fuel costs per mile.

As to environmental and health characteristics, methanol is probably superior to gasoline from an environmental and health standpoint. The methanol engines produce lower regulated exhaust emissions and methanol spills would be more environmentally benign than spills of petroleum products.

A couple of observations on its status relative to other fuels: Unlike direct liquefaction of coal, the technology to produce methanol is here today. Also methanol offers the opportunity to utilize coal not recoverable for direct liquefaction purposes and to transition to renewable feedstocks.

But in the area of obstacles, and we have made some comments about that, any optimism concerning methanol needs to be tempered with a number of realities. Methanol from coal is not being produced commercially today. Vehicles optimized for its use are not being produced. A methanol distribution infrastructure does not exist.

The problem of simultaneously converting both the auto and automotive fuel industries will not be easily overcome and, of course, we have the retrofitting-type problem that could occur depending on how and when it is introduced.

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[2]The report referred to, "Water Supply Should Not Be an Obstacle To Meeting Energy Development Goals," CED-80-30, January 24, 1980, may be secured at the General Accounting Office or may be reviewed in the subcommittee files.

Also, as with most synthetic fuel options, environmentally based opposition to the necessary increases in coal production and plant sitings will have to be overcome before any nationwide methanol program could be expected.

With methanol, the Nation does have a synthetic fuel option that it can potentially begin producing and using with existing technology at what appear to be competitive costs. In addition, compared to gasoline, numerous studies have shown methanol has generally favorable environmental characteristics. While methanol's potential is vast, several important obstacles do remain, to be resolved, however, before its widespread use could become a reality.

[Testimony resumes on p. 294.]

[Mr. Peach's prepared statement follows:]

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

FOR RELEASE ON DELIVERY
EXPECTED AT 3:15 p.m.
THURSDAY, DECEMBER 18, 1980

STATEMENT OF
J. DEXTER PEACH, DIRECTOR
ENERGY AND MINERALS DIVISION
BEFORE THE
SUBCOMMITTEE ON ENERGY AND POWER
HOUSE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to be here today to discuss the potential of alternative liquid fuels for automotive use. In addressing this subject, I will direct my remarks primarily to alcohol fuels because these fuels have high potential for replacing petroleum-derived fuels in the near-term.

We have done a substantial amount of work in the alcohol fuels area and over the past year have issued three reports on the subject. 1/ I am submitting a copy of each report for the record. Based on our work, we have determined that alcohol fuels have vast potential for replacing petroleum fuels, particularly in the automotive sector. Perhaps even more important, unlike some other synthetic fuel options which

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1/"Potential of Ethanol As A Motor Vehicle Fuel" (EMD-80-73, June 3, 1980); "Concerns Over the Department of Energy's (DOE's) Program and Organization for Developing and Promoting the Use of Alcohol Fuels" (EMD-80-88, July 22, 1980); "Conduct of DOE's Gasohol Study Group: Issues and Observations" (EMD-80-128, Sept. 30, 1980).

still require extensive R&D before commercialization can be expected, the technology to produce alcohol fuels--both ethanol and methanol--is here today. Ethanol is now making a contribution toward stretching available gasoline supplies and methanol could eventually be produced in sufficient quantity to totally replace gasoline.

Our work in the alcohol fuels area has addressed both ethanol and methanol. Concerning ethanol we found that

--there is minimal but expanding use in a blend of 10-percent ethanol and 90-percent unleaded gasoline (commonly referred to as gasohol) which is now helping to stretch gasoline supplies;

--the current selling price of ethanol is about $1.75 per gallon, but as new, more efficient distilleries are put into use, the price could decline;

--because of feedstock constraints, ethanol's potential will most likely be limited to the role of a valuable gasoline extender; and

--ethanol commercialization has benefited substantially from a waiver of Federal gasoline taxes (amounting to a subsidy of 40 cents a gallon in the form of gasohol) and even larger waivers of some State gasoline taxes.

We also examined methanol in considerable detail and from many different perspectives. Based on our work, we are highly optimistic about methanol's potential as an automotive fuel.

In discussing methanol, let me address its potential more specifically in terms of its (1) production, (2) use as an automotive fuel, (3) environmental and health characteristics, and (4) status relative to other synthetic fuel options.

METHANOL PRODUCTION

Methanol offers a synthetic fuel option with highly promising production potential that the Nation could begin implementing within existing technology. Methanol can be produced from almost any organic feedstock, including coal, natural gas, trees, and municipal solid waste. Hence, unlike ethanol, there is no shortage of available feedstock to produce methanol. Methanol is currently produced in the United States primarily from natural gas. Because of limited availability of natural gas, production of methanol for automotive fuel use is expected to be from coal. In this connection, based on Department of the Interior assessments, sufficient economically recoverable coal reserves exist to enable enough methanol production to totally replace gasoline for perhaps 100 years while still enabling almost a doubling of current domestic demand for other uses. In addition, development of in-situ processing technology could make enough additional coal reserves available to extend this production potential several times longer. Methanol production potential could be further expanded with the use of renewable feedstocks such as trees, municipal solid waste, and crop residues.

Although the same feedstocks could be used to produce ethanol, almost four times as much methanol could be produced with those same feedstocks.

Many reports on the subject of synthetic fuels development have predicted that such development will stimulate a demand for water that will virtually exhaust unused water supplies in the water-short West. Based on data available to GAO, however, water availability may not be the obstacle to energy development it is often thought to be. In this connection, GAO's January 1980 report 1/ on the availability of water for energy development in the West, concluded that sufficient water is available from Federal reservoirs to meet energy development needs, including the production of synthetic fuels, without interfering with existing water users through the year 2000. Extending this projection beyond the year 2000, recent Department of the Interior estimates of water availability in the Missouri River Basin (a region rich in coal deposits and projected for heavy energy development) show a huge reserve of uncommitted water through the year 2050.

Methanol production is also not constrained by undeveloped technology. Although currently in the United States no commercial-scale methanol from coal production plant is in

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1/"Water Supply Should Not Be An Obstacle to Meeting Energy Development Goals" (CED-80-30, Jan. 24, 1980).

operation, the technology to produce methanol has been commercial for years. Methanol was produced from coal in France in the late 1940s and in the mid-1950s, DuPont Chemical Company operated a methanol from coal plant in the United States. As cheap natural gas became available, coal was replaced as a feedstock. However, the production of methanol from coal received renewed interest after the 1973-1974 oil embargo and in 1974 the Federal Energy Administration (a predecessor agency to DOE) recognized methanol from coal technology as a near-term energy self-sufficiency option. Today, methanol can be produced with available technology using almost any quality coal. Even high sulfur coal, which presents problems for direct combustion, can be used because the sulfur is removed during methanol processing. Our work has concentrated on methanol production from coal. However, in a recent report entitled "Energy from Biological Processes", the Office of Technology Assessment concluded that methanol can probably be produced from wood with existing technology. It further stated that production from crop residues and other renewable cellulosic feedstocks needed to be demonstrated.

Production cost estimates are highly encouraging as well. While precise cost estimates are not available since no commercial methanol from coal plant is in operation today, available projections suggest that methanol from coal production costs could be in the range of 50 cents a gallon at today's prices. Cost estimates for production from wood are somewhat higher--in the range of 65 to 75 cents a gallon. Thus, production capability at economically viable prices should not be an obstacle to a national scale methanol program.

USE AS AN AUTOMOTIVE FUEL

Methanol can be used as an automotive fuel within existing technology as well. Methanol can be used in small blending proportions in unmodified automobiles today, but problems with phase separation, vapor lock, and materials compatibility have led to the view that methanol would be optimally used in vehicles modified to adapt to, and take full advantage of, its chemical properties. The primary modifications involve increasing fuel flow and engine compression, replacing various incompatible materials, and possibly adding a system to preheat the fuel mixture to enhance combustion. Increased fuel flow and engine compression are necessary to adapt to methanol's corrosive properties. Finally, to overcome methanol's reduced cold starting capability, engineering modifications to the fuel intake system may be required. However, this may not be necessary if cold starting aids such as ethers or, in fact, even gasoline are added to the methanol.

Auto industry representatives told us the vehicle modifications necessary would be achievable on the assembly line within existing technology at relatively minor cost. They



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also indicated vehicles optimized for methanol use could be available by the time the fuel is available on a widespread basis. Available performance test data on such engines is very encouraging. Testing on modified engines show significant increases in fuel efficiency. Thus, while methanol has only about one-half the energy content of gasoline, methanol optimized engines should yield significantly more than one-half as many miles per gallon. At today's costs for gasoline and projected costs for methanol, this efficiency gain could result in lower fuel costs per mile. Testing also has shown methanol to provide increased power and lower risk of vapor lock than existing gasoline engines. Finally, based on limited discussions with Environmental Protection Agency staff, their preliminary thinking is that methanol marketing as a straight fuel in redesigned vehicles will not be constrained by restrictions on new fuels set forth in the Clean Air Act.

ENVIRONMENTAL AND HEALTH CHARACTERISTICS

In terms of its environmental and health characteristics, straight methanol is also possibly superior to gasoline. Engine tests show straight methanol produces generally lower regulated exhaust emissions, especially nitrogen oxide. In addition, since methanol does not contain aromatic hydrocarbons (such as benzene) which are used in gasoline to boost octane, its evaporative and unburned fuel emissions are probably less toxic and possibly pose less of a carcinogenic risk. Methanol combustion does result in increased unregulated aldehyde emissions but these emissions are thought to be easily controlled with catalytic converters.

In terms of protecting water quality, methanol is also possibly more environmentally benign. Unlike petroleum products, it is completely soluble in water and does not cause lasting damage to aquatic life in the event of a spill. From the standpoint of human health, methanol is probably less toxic to breathe and more toxic to drink. Steps, such as addition of an unpleasant smell to the fuel, will be necessary to prevent the fuel from being ingested as drinking alcohol.

STATUS RELATIVE TO OTHER SYNTHETIC FUELS

Compared to other commonly discussed synthetic fuel options, such as direct liquefaction of coal, methanol has a number of distinct advantages. Perhaps most importantly, the technology to begin producing methanol from coal is here today. As we pointed out in our August 1980 Report to the Congress on coal liquefaction, 1/ further R&D is needed on direct liquefaction and it is unlikely that any commercial plants employing such technology will be operating in the 1980s. On the other hand, as I indicated earlier, methanol production

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1/"Liquefying Coal for Future Energy Needs" (EMD-80-84, Aug. 12, 1980).

technology is commercially available. Methanol has a number of other advantages as well. It offers the opportunity to utilize coal not recoverable for direct liquefaction purposes and the potential for transitioning to other renewable feedstocks. Also, in engines optimized for its use, it will likely burn more efficiently.

OBSTACLES TO METHANOL USE

While methanol has vast potential and many advantages relative to other options, our optimism about methanol as a fuel must be tempered with several realities. Neither methanol from coal nor vehicles optimized for its use are being domestically produced today. Further, no infrastructure exists for distributing methanol from its production source to points of sale. The problem of simultaneously converting both the auto and automotive fuel industries will not be easily overcome. As a step toward solving this problem, however, it may be possible to provide a market for early methanol production by using the methanol as a gas turbine fuel for generating electricity. Available testing shows methanol burns cleanly and efficiently in this capacity. Another early step might be the use of methanol in captive vehicle fleets, such as the Federal fleet, to provide a demonstration medium and early market for optimized methanol vehicles.

Another issue, common to other synthetic fuel options, is the question of environmental impacts resulting from greatly expanded coal production. If all the Nation's gasoline were to be replaced with methanol made from coal, coal production would have to more than double from its current level and much opposition to such increased mining exists. Plant siting could also pose problems. Further, the long-term effects on atmospheric carbon dioxide levels will have to be assessed. A balance of fuel needs versus environmental concerns will have to be struck before a nationwide methanol program can be expected.

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In summary, with methanol the Nation has a synthetic fuel option that it can potentially begin producing and using with existing technology at competitive costs. In addition, compared to gasoline, numerous studies have shown that methanol has generally favorable environmental characteristics. While methanol's potential is vast, several important obstacles remain to be resolved before its widespread use can become a reality.

Mr. Chairman, that concludes my prepared statement. We would be pleased to answer any questions at this time.

Mr. OTTINGER. Thank you very much.

Dr. Gibbons, let me get that statement that I did not quite understand until I asked you about it.

First, if in fact our oil use—which I think is our prime problem in the country—is 54 percent in the transportation sector, then why is the No. 1 premium for methanol from stationary sources, which I would guess account for—I do not know, the figures I have seen, it is 9 percent for production of electricity and something like 17 percent oil used for industry and agriculture overall, so it ought to be somewhere around 12, 15 percent; why does it seem more advantageous, however you put it, to take 15 percent of oil use in terms of displacing imported oil and the 54 percent transportation?

Mr. GIBBONS. I have to derive some numbers from memory. I would be happy to correct them for the record, Mr. Chairman. The use of liquids in the transportation sector, as you know, is actually falling now quite steadily because of the incorporation of much more efficient machines on the road. My round numbers indicate that about 10 percent of the oil—that is close to your number—goes to the utilities. About one-fourth each goes to buildings and to industry. So that accounts for about 60 percent. Then about 40 percent—or it is moving toward 40 this year—goes into transportation. Therefore, my opening caveat was if we are worried about petroleum, let us not forget at least half and maybe, in fact, closer to 60 percent is not going into transportation. That is not to say that transportation is not a terribly important and high-leverage area to be working on.

Mr. OTTINGER. I would like to see those figures, because they are——

Mr. GIBBONS. I would be happy to supply those for you.

[The following information was received for the record:]

PERCENTAGE BREAKDOWN OF OIL USE BY SECTOR FOR 1975, 1978, AND 1980

| Year | Industry | Buildings | Electric utilities | 3 sectors | Transportation | |
|---|---|---|---|---|---|---|
| | | | | | Total | Motor gasoline |
| 1975 | 19.6 | 16.8 | 9.8 | 46.2 | 53.8 | 39.2 |
| 1978 | 18.7 | 18.2 | 10.0 | 47.0 | 53.0 | 37.5 |
| 1980 (first) | 21.8 | 17.2 | 9.1 | 48.3 | 51.7 | 36.5 |
| 1985 (half projection) | 16.7 | 19.1 | 4.1 | 39.9 | 61.1 | 40.0 |

Although transportation still uses more than half of the petroleum used in the United States, the trend has been downward in the last few years. This is largely a result of the decline of motor gasoline use which has been more rapid than for other petroleum uses. The figures show that motor gasoline has dropped from 39.2 to 36.5 percent of total petroleum use since 1975. It is expected, however, that this trend will reverse in the next few years because of the very large potential for oil conservation in industry and buildings and backout of oil in the utility sector. Therefore, even though oil use by transportation will continue to decline as the nation's automobile fleet reaches higher mileage standards, use by stationary sectors should decline even more rapidly leading to a reversal of the percentage trends. The line in the chart for 1985, taken from the most recent forecast of the Energy Information Administration shows this phenomenon. It must be emphasized, though, that actual demand for all the sectors should be decreasing.

Mr. OTTINGER. They are not what I last saw.

Mr. GIBBONS. That was the basis of my initial caveat, to set the stage for the transportation.

Mr. OTTINGER. Your figures on oil use—not liquid fuels use—but on oil use in the United States are now about twenty-five percent?

Mr. GIBBONS. From my memory. Sometimes it is faulty. About 25 percent each in the industry and the buildings.

Mr. OTTINGER. Industry and buildings?

Mr. GIBBONS. About 10 percent to utilities; and about 40 percent into transportation.

Mr. OTTINGER. What is the other one? Forty percent transportation? What is the other 25 percent?

Mr. GIBBONS. Twenty-five percent into buildings and 25 percent into industry. Now, of course, there is residual oil, the middle distillates, and the like. There are ways to change a refinery to move from one to another. There is a substantial amount of light distillates that are used in industry and home heating and the like which also can endure fuel switching, just as one can in the automobile. It seems to me one needs to look at that entire package of options in terms of where the best investments are and the timing for each. That was only meant to be an introductory point and then move on into transportation. I did not mean to divert you.

Mr. OTTINGER. It is very significant from the point of view of my own thinking. From what the committee does in addressing the problem it is important to get those figures accurately.

Mr. GIBBONS. I would be happy to check my memory, Mr. Chairman. I also point out in these other sectors—just as in transportation—the opportunity to respond to higher price of liquids through increased efficiency is very high, and with your leadership and others the country is beginning to take advantage of that fact.

Mr. OTTINGER. The cost figures—maybe Mr. Hunt can do this better than I can—the cost figures we got in the testimony from the previous panel, the cost figures of both you and Mr. Peach seem somewhat at variance.

Mr. GIBBONS. Yes, sir. I would only point out that all of us should be careful—and we will try to do so—about definitions. For instance, what capital charges assumptions is one making? Is one talking about the price at the plant or the pump? That is a substantial difference. I believe when one lays these cost figures out on a self-consistent basis, that you will find not that much of a difference between the numbers.

Mr. OTTINGER. Do you want to follow that up?

Mr. HUNT. Yes, Mr. Chairman. Thank you.

I do agree that it is critical as to what stage in the process you use for your cost or price comparison. The committee staff has been aware for some time that there seems to be a range of costs all of which seem competitive with gasoline at today's prices running a factory-door cost, including capital charges, construction charges, and some working capital with medium- to large-sized plant that runs somewhere under 50 cents a gallon, say in the 30- to 50-cent range. The range you have in your testimony of 65 to about 90-

some-odd cents a gallon at retail seems fully consistent with the testimony that we received before. I think it should be noted that that would be competitive with gasoline at today's pump prices, taking account of the increased efficiency per Btu that you get by virtue of the high octane of the methanol itself.

Mr. GIBBONS. Yes, sir. It seeems to me we are chasing a moving target. It is clear to me the time is now to be quite serious about it.

Mr. HUNT. Thank you.

Mr. OTTINGER. I have no further questions.

Mr. Hunt?

Mr. HUNT. Mr. Childress, in your testimony, you made reference to not closing any options. I wonder whether you heard any of the testimony this morning with respect to the Texaco-controlled combustion system and the flexibility that it offers in terms of being able to burn methanol, ethanol, JP-8, JP-6, JP-4, diesel fuel, leaded, unleaded gasoline? Would you consider this to be an advantageous engine to pursue and promote because it does provide that flexibility of fuels?

Mr. CHILDRESS. I would consider the concept an advantageous one. I am not familiar—other than having had it described to me—with that particular engine, but I think the development of a multifuel engine that can operate within all the constraints that U.S. auto engines have to operate within should be pursued aggressively. Again, it is entirely consistent with a philosophy of getting the best that is out there and giving it a chance in the marketplace.

Mr. HUNT. I do not want to ask you for any premature comments regarding your final study. So if this does border on something that is in the study that you would not like to release now, just pass the question.

It has come to the subcommittee staff's attention that the Canadian Government is doing a great deal in the field of methanol and methyl fuels. Has your organization been aware of this or tracked any of that work?

Mr. CHILDRESS. Only recently. It will not play a major or any part in the final report. This is the report that has come out within the past 6 weeks, I believe.

Mr. HUNT. Yes.

Mr. CHILDRESS. It would be premature for the Commission to base any of its recommendations on something that has come to its knowledge that late.

Mr. HUNT. I think one of the prior witnesses pointed out there seemed to be great advantages in moving to a currency fuel such as methanol which can be produced from indigenous resources in almost any country in the world.

Mr. CHILDRESS. Certainly.

Mr. HUNT. Such a fuel that could be produced in Senegal out of biomass or in the United States out of coal or in Canada out of tar sands would promote international commerce and able to take advantage of basic research that goes on overseas.

Mr. CHILDRESS. Also from the flexibility of the product. As has been pointed out, the plant is entirely consistent with the production of ammonia. If, for instance, the economics reach the point at which it makes more sense to make gasoline from methanol and keep the present vehicle fleet in place, fine. You have that plant in place. There is a lot going for it.

Mr. HUNT. Is your study going to address the scalar factor with respect to how big the plant should be or not?

Mr. CHILDRESS. It will not get into that great a detail on the sizing factor. The report will be dealing with the public policy issues; that is whether it is desirable to displace petroleum with methanol rather than indentifying the most efficient way to produce methanol. There is a presumption in the report based on analysis of economics, international environmental and energy poled, that methanol makes sense. We are looking at the policy levers that could encourage the greater production and use.

Mr. HUNT. Thank you, Mr. Childress.

Mr. Peach, I do not believe you mentioned it in your testimony, but am I correct that in one of the GAO reports you indicate that if you were starting with a fixed amount of biomass feedstock, you could get almost four times as much methanol out of the gasification of that feedstock as you could ethanol from normal fermentation processes and subsequent distillation?

Mr. PEACH. I think that is correct; right. The essential feature is when you are dealing with those kinds of cellulose feedstocks, a substantial amount more return can be expected from methanol than ethanol.

Mr. HUNT. Thank you very much.

Thank you, Mr. Chairman.

Mr. OTTINGER. All right. I want to thank you for your help today. I look forward to working with you in the future on this subject, which is one of great interest to the committee. I thank all the witnesses for this help today. The hearings will be adjourned today and kept open for 10 days to receive any additional testimony.

I very much would appreciate it if you would let my office know with respect to the use figures and the water issue as well, if you would inform both the committee and me of that, Mr. Peach.

Mr. PEACH. Yes, sir.

Mr. OTTINGER. I would appreciate it.

The hearings are adjourned.

[The following letters were received for the record:]

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 24 1980

Honorable John D. Dingell
Chairman, Subcommittee on
Energy and Power
Committee on Interstate and
Foreign Commerce
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

The Environmental Protection Agency (EPA) fully recognizes the importance of alternative fuels in lessening our nation's dependence on foreign crude oil. We are, therefore, pleased to take the opportunity provided by your Subcommittee's hearing on the subject to offer our views and explain our efforts in this area.

The EPA is committed to assisting the nation in the development of alternative liquid fuels. In light of the critical relationships between energy production and usage, and environmental protection, alternative fuels policy development should be considered within a broad energy and environmental framework. In this regard, the Agency firmly believes that alternative fuels can be developed in a way which will not only reduce petroleum demand but also improve environmental quality. EPA is committed to this idea and is taking positive steps to see that it is achieved.

We would like to divide our comments into two areas of concern. The first deals with the production aspects of synthetic fuels, the second with the use of the fuel.

With respect to the production of alternative fuels, the Agency has established an Alternate Fuels Group which is developing a series of Pollution Control Guidance Documents. These documents will provide timely assistance to writers and developers of permits, so that the synfuels industry may proceed according to the timetable set by the Congress in the Energy Security Act. This is the Agency's first step in assuring that the construction and operation of these facilities will be environmentally sound.

The Agency is also very interested in the environmental effects of the many end uses of synfuels, and is actively working in this area. With respect to the automotive uses, the Agency has the authority to regulate new fuels and fuel additives under section 211(f) of the Clean Air Act (Act), which prohibits their introduction into commerce in unleaded fuel without EPA approval. The Act allows for a waiver of the prohibition if the fuel manufacturer can establish that the fuel or additive will not cause vehicles to fail applicable emission standards. The Agency works closely with waiver applicants and potential applicants to ensure that relevant data are developed, assembled, and comprehensively evaluated. These efforts have resulted in the granting of waivers for Gasohol (10% ethanol/90% unleaded gasoline), tertiary butyl alcohol (TBA, 0-7% in unleaded gasoline), methyl tertiary butyl ether (MTBE, 0-7% in unleaded gasoline), Sun's oxygenated hydrocarbon (2.75% methanol, 2.75% TBA, in unleaded gasoline), and TC-11064, a Texaco deposit control additive (60 pounds per thousand barrels of unleaded gasoline).

In addition, the Agency provides allowances for the legitimate experimentation with alternative fuels and modified emission controls. Not only are we concerned with the work in this country, but also we are keeping abreast of worldwide efforts. The Agency is working with the Department of Energy (DOE) in assessing data developed by DOE, the automotive industry, the academic community, the petroleum industry, and other governmental bodies such as the California Energy Commission. Particular emphasis has been placed on ethanol and methanol as gasoline extenders and as pure fuels. Tests on the use of methanol in a diesel engine are being conducted by an Agency contractor and Agency tests of alcohols and other alternative fuels are planned for next year.

Looking to the future, there are three general scenarios under which ethanol and methanol might be utilized on a large scale. The first two scenarios involve the use of ethanol or methanol in vehicles which were not actually designed for such fuels. The third scenario involves the mass production of vehicles which would be designed and optimized specifically for alcohol (most likely methanol) combustion.

First, an additive might be added directly to unleaded gasoline such that no alteration to the vehicle is required. This has been the case for all waiver grants to date and allows vehicles to retain the flexibility of using a variety of fuels. In some cases the additives have exhibited no significant impact on emission performance, and in other cases significant differences have occurred. For example, Gasohol use resulted in significant decreases in carbon monoxide emissions and increases in evaporative hydrocarbon emissions. The use of methanol by itself in gasoline, which has yet to receive a waiver, has demonstrated a variety of problems that could be expected if used in current automobiles without any hardware modifications. For example, evaporative emissions would be higher than with ethanol, vapor locking would be more of a problem, materials compatibility problems with metals and elastomers would be more apparent, and phase separation would be more likely. With respect to ethanol versus methanol blends, General Motors and Chrysler have stated that new car warranties will remain in effect only for ethanol/gasoline blends. (Note: There is no prohibition on the use of methanol in leaded gasolines so use of this blend would be legal. However, the same problems would be present.)

In the second scenario, modification of fuel systems and emission controls in existing vehicles would be required to allow the use of a fuel or additive in pure form or significant concentrations. In the case of a conversion from gasoline to pure alcohol, this would entail precise carburetor modifications and the replacement of some fuel system components with more compatible materials.

Two potential problems would be introduced if the general motorist were to modify his vehicle. First, if the modification were not done correctly, vehicle emissions could exceed the applicable standards. Secondly, such vehicles likely could only run on this fuel, and would therefore need to have it widely available. The Agency believes, however, that this effort could be used in current vehicles within the context of a controlled program, such as a well maintained fleet, where qualified personnel would be responsible for the modification and continual maintenance of the vehicles.

There would still be problems (e.g., deterioration of polyelastomers) which could cause increased emissions and/or poor performance. But, these problems could be isolated and controlled much better in fleets than in the general marketplace. The Agency has a continuing effort to grant approval to alcohol-fueled automobile fleets. Participants agree to closely control the fleet and to provide the Agency with information and control data in return for assurances against violations of the Act. The Agency supports these controlled experiments as a means of learning more about the emissions and fuel economy performance of alcohol fuels.

These first two scenarios involve the use of alcohol blends or pure alcohol fuels in vehicles which were not designed for their use. These scenarios might well occur in the near future and could contribute to petroleum conservation. The largest petroleum savings would be realized, however, if new production vehicles were designed for an alternative fuel, which will likely not occur until a consensus is reached that an alternative fuel is clean, efficient, and available.

In the third scenario, vehicles would be designed and built to operate on an alternative fuel, such as methanol. Inherent design change could alleviate the problems that could be expected with converted vehicles and would provide for the most efficient utilization of the fuel. This approach is quite promising, and regulations could be amended to specify the quality of methanol (or other fuels) to be used for testing, as is presently specified for gasoline and diesel fuels. There is evidence to suggest that vehicles designed and optimized for methanol combustion might well be more energy efficient (on an energy content basis) than current gasoline and diesel-fueled vehicles. In addition, methanol vehicles would likely emit less oxides of nitrogen and, compared to diesel engines, less particulate matter as well. Problems which were mentioned above for methanol blends, such as higher evaporative emissions and fuel system materials incompatibility, would likely be easily solved by proper design and optimization at the vehicle engineering stage.

While it is difficult to make an overall policy judgement at this early date, it now appears that pure methanol fuel may offer environmental, cost, and efficiency advantages while reducing our need for imported oil. We are continuing our investigation in this area, and our program office will be sending additional material to the Subcommittee in early January on this perspective of the potential of methanol as an alternative motor vehicle fuel.

EPA is currently following programs initiated by the University of Santa Clara, the California Energy Commission, the U.S. Postal Service, the Urban Mass Transit Authority, the University of Miami, and the Department of Energy, to review the use of vehicles with pure methanol fuels.

In summary, EPA is actively encouraging the development and use of clean and efficient alternative fuels. We currently believe that the use of pure methanol, in vehicles designed and optimized for pure methanol combustion, offers the most potential to reduce our dependence on foreign oil while simultaneously improving environmental quality. We are continuing to expand our knowledge and improve our analyses in this area.

Sincerely yours,

Jeffrey G. Miller
Acting Assistant Administrator
for Enforcement

ENERGY TRANSITION CORPORATION

ROBERT W. FRI, PRESIDENT
1101 CONNECTICUT AVENUE, N. W.
WASHINGTON, D. C. 20036
(202) 457-0868

December 19, 1980

The Honorable John Dingell, Chairman
Subcommittee on Energy & Power
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

At the hearing on Alternative Fuels and Engines chaired by Rep. Ottinger on December 18, you requested the witnesses to submit additional information on the impact of regulations on the development of new transportation fuels and power plants. Although not myself a witness, I am taking the liberty of writing this letter in response to your request.

My interest in this subject arises from three sources. First, as Deputy Administrator and Acting Administrator of the Environmental Protection Agency (EPA) from 1971-1973, I have some background in the administration of the Clean Air Act (CAA) provisions that affect automotive fuels and engines. Second, our company, Energy Transition Corporation (ETCO), is aggressively developing several projects to produce methanol from coal and peat primarily to provide transportation fuels. As a result, we have been quite active in working with the Bank of America, the State of North Carolina, and others to promote the use of methanol in automobiles. Third, ETCO conceived of the idea of converting automobile fuel efficiency standards to the basis of miles per million Btu (M/MMBtu), and on May 2 requested action from the Department of Transportation (DOT) and EPA to implement this concept. I note that two of your witnesses - Merle Fisher of the Bank of America and James Childress of the National Alcohol Fuels Commission - recommended this concept during the hearing.

Impact of EPA Regulations

In 1970, the CAA was amended to stiffen substantially the requirements for reducing automotive pollution. At the tire, Congress based its actions on two assumptions. One was that progress toward control of automotive emissions had been too slow, and so more stringent emission targets and deadlines were required to get action. The second and implicit assumption was that existing spark-ignition, gasoline-fueled power plant technology would continue to dominate the automotive market. Hence, the statute was written with this technology in mind.

While these assumptions were probably reasonable at the time, they resulted in 1970 CAA amendments that mitigated against innovation in automotive engines and fuels. Three aspects of the statute are particularly important in this regard:

1. The compliance deadlines required automotive manufacturers to use the most readily available technology to meet emissions standards. Catalytic converters thus became the preferred technological solution, since time was not available to develop and deploy new engines or fuels that might have done the job better. Now that the industry is locked into these technologies, no great incentive exists to develop alternatives, especially in light of the financial difficulties of some of the large automakers.

2. Since the technology to control automotive emissions had a tendency to degrade automotive performance, especially before 1975, Congress wanted to ensure that the control devices were not removed. As a result, the Act contains penalties for tampering with the engine and control systems. This section of the Act was drawn so broadly that conversion of any existing automobile to alternate fuels or engines is likely to produce a violation of the anti-tampering provision.

3. Catalytic converters can be poisoned by lead and other fuel additives, and Congress wished to prevent this result. Moreover, there was concern that new additives and fuels might produce emissions that were harmful to human health. For both reasons, Congress prohibited new fuels and fuel additives unless specifically approved by EPA. Consequently, introduction of new fuels, even for demonstration purposes, require a waiver from EPA.

This combination of circumstances has a chilling effect on the introduction of new automotive engines and fuels. To overstate somewhat, major automakers have little incentive to innovate, and developers of new engines and fuels must obtain waivers even to demonstrate their technologies. Obtaining waivers requires fairly extensive testing. The test requirements for methanol have been documented in several EPA decisions denying waiver requests (see, for example, page 53861 of the Federal Register of August 13, 1980).

The energy problem has of course sharpened the need to introduce new automotive fuels and engines that reduce oil imports, improve fuel efficiency, and continue to meet emission standards. Thus, the assumptions on which the 1970 Act rested have changed with time, and the Act should be revised accordingly. The anti-tampering and fuel waiver provisions of the CAA should not stand in the way of demonstrating technologies to meet new needs. I do not believe that the environment would be harmed by permitting these technology demonstrations on a reasonably large scale, based on a showing that the demonstration was adequately controlled.

Automotive Fuel Efficiency Standards

The Energy Policy and Coordination Act (EPCA) imposed an automotive fuel efficiency program, requiring automobiles to reach an efficiency of 27.5 miles per gallon of gasoline by 1985. Like the CAA, EPCA rested on an assumption that is no longer valid - that gasoline will remain the preferred fuel for automobiles. The energy problem now compels us to seek alternatives to gasoline, and preferably alternatives that are not based on petroleum.

The existing automotive fuel efficiency program mitigates against the introduction of new fuels by treating a gallon of any fuel just like a gallon of gasoline. Alcohol fuels have fewer Btu's per gallon than gasoline, and so their use actually decreases fuel efficiency as measured on a mile per gallon basis. Similarly, no credit is given for substituting non-petroleum fuels for gasoline, although the clear intent of the EPCA was to reduce petroleum consumption. These are powerful disincentives for the use of alcohol fuels.

Automotive efficiency should not be measured by the number of gallons of liquid delivered to the fuel tank, but by the energy required to operate a vehicle. In other words, the relevant measure is not miles per gallon but M/MMBtu. Such a measure would introduce incentives for the use of alcohol fuels. Methanol, for example, can be used more efficiently in an automotive engine than can gasoline, and thus a M/MMBtu standard would encourage the use of methanol as a way to meet automotive efficiency objectives. Of course, eliminating non-petroleum fuels from the calculation of automotive efficiency would also create a powerful incentive to shift to alternate fuels.

ETCO recognized this problem with EPCA early this year, and on May 2 we wrote DOT and EPA requesting action to convert the automotive fuel efficiency program to a M/MMBtu basis.

Under the statute, DOT must first declare alcohol fuels to be an automotive fuel, and then EPA must determine the basis on which alcohol fuels should be considered in calculating automotive fuel efficiency. I have attached our letters of May 2 to both agencies, and these letters describe in detail our concept in the actions that we requested.

On June 17, the Secretary of Transportation acknowledged our request (copy attached) and agreed to initiate a rulemaking to declare alcohol as an automotive fuel. We understand that the staff of the National Highway Traffic Safety Administration has prepared the necessary documents, but that the recommendation has not yet cleared all the reviewing authorities within DOT.

On August 29, we received a response from EPA (copy attached). Their response seems to miss the point of our recommendation. In particular, EPA feels it is premature to act because no methanol engine has been developed. It was the purpose of our recommendation to anticipate the development of alcohol engines and to act now to encourage their use.

We were pleased that Messrs. Fisher and Childress recommended the M/MMBtu concept at your hearing on December 18. We believe their recommendations lend weight to the proposals that ETCO made on May 2. The actions necessary to implement this concept can, I believe, be taken under existing law by DOT and EPA. Prompt administrative action by these agencies would probably achieve the desired objective more quickly than would legislation. Although ETCO will continue to press forward with the proposals we made nearly eight months ago, an expression of interest from your Subcommittee would of course be helpful in assuring prompt action.

Since ETCO was not represented as a witness at the December 18 hearings, we understand that it may not be appropriate to enter this letter into the record. However, we believed we could contribute information relevant to your interest in regulatory obstacles to the introduction of new automotive fuels engines, and I hope our comments are of help to you.

If you or your staff have any questions, we would be pleased to respond to them.

Respectfully,

Robert W. Fri

RWF/ngs
attachments
cc: Hon. Richard Ottinger
Peter Hunt
Merle Fisher
James Childress

ENERGY TRANSITION CORPORATION

ROBERT W. FRI, PRESIDENT
1101 CONNECTICUT AVENUE, N. W.
WASHINGTON, D. C. 20036
(202) 457-0868

May 2, 1980

The Honorable Douglas M. Costle
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Administrator:

The purpose of this letter is to propose that you initiate a rulemaking designed to encourage the use of alcohol fuels in automobiles sold in the United States. The recommended rule, which you have the power to adopt pursuant to 15 U.S.C. 2003(d)(2), would establish the relative end-use energy efficiency as the basis for computing the volume of alcohol fuel equivalent to one gallon of gasoline. Since we believe that engines can be designed to use alcohol fuels more efficiently than gasoline, this rule would encourage the sale of alcohol engines, and thus the production of alcohol as a non-petroleum transportation fuel.

## I. Background

The President, the Secretary of Energy, and many other public and private officials encourage the use of alcohol fuels as a substitute for gasoline. Other countries, notably Brazil, have made a national commitment to alcohol fuels. These fuels are now widely accepted as a feasible alternative to gasoline, and potentially a major source of fuel to reduce oil imports.

In general, the initial introduction of alcohol fuels in the U.S. has been through gasohol - typically a 10 percent or so blend of alcohol with gasoline. Gasohol is unquestionably a good starting point for introducing alcohol, but if a major displacement of gasoline is to occur, alcohol must penetrate more than 10 percent of the automotive fuels market. The purpose of this request is to provide an incentive to develop engines able to use high proportions of alcohol.

Using pure alcohol, or very high proportions of alcohol, requires modification of the gasoline-powered engine. Such modifications have been studied extensively by Volvo and Volkswagen.

Brazil has compelled the use of such engines, and both Ford and General Motors have announced the commitment of hundreds of millions of dollars to comply with this government requirement. In this country, the Bank of America is converting a portion of its fleet to methanol, using production model Fords converted for this purpose. Furthermore, the California Energy Commission has adopted a resolution (copy attached) which states, among other things, that the Commission intends to continue to support:

> "...programs that will enable state and local governments and private industries to convert captive fleets to use of straight alcohol fuels, and vehicle manufacturers to offer mass produced vehicles capable of using such fuels."

Because of the momentum already building toward the use of pure, or high proportions of, alcohol fuels, we regard the incentive we recommend as timely. We also believe that it encourages the use of that which is technologically possible today.

Congress recognized the need to bring new engine designs within the scope of the automotive fuel economy program in recent legislation concerning electric vehicles. Its action parallels our proposal by requiring the Secretary of Energy to determine the "...equivalent petroleum based fuel economy" for such vehicles, thus providing an incentive to electric vehicle production. Our proposal seeks to establish a similar incentive for alcohol-fueled automobiles.

Energy Transition Corporation (ETCO) has a major interest in the increased use of alcohol fuels. ETCO is developing several coal-sourced methanol plants, one of which (in conjunction with W.R. Grace & Co.) has been publicly announced. Although the transportation market may not be the earliest market for coal-sourced methanol, it can become the largest and highest-value methanol market long term; thus, ETCO has an interest in seeing this market develop. It should be noted, however, that: (1) our recommendation is not limited to methanol from coal, but encompasses alcohol fuels from whatever source; and (2) we do not recommend compelling the use of alcohol fuels, but only encouraging their use where it is advantageous to the national interest and the automobile manufacturers to do so.

## II. Recommendation

You have the power under 15 U.S.C. 2003(d)(2) to determine by rule the quantity of any automotive fuel that is equivalent to one gallon of gasoline. This quantity would then be used in Corporate Average Fuel Economy (CAFE) calculations. We recommend that you establish end-use energy efficiency as the basis for determining this equivalent quantity.

Considerable research here and abroad has established the practicality of using high proportions of alcohol fuels blended with gasoline, and of using pure alcohol fuels. This research also shows that alcohol-fueled engines can operate considerably more efficiently than gasoline engines. The Bank of America is converting part of its fleet to methanol fuel, and California has conducted field tests of alcohol fuels. We understand that early results suggest that only 1.0 to 1.4 gallons of methanol are needed to replace one gallon of gasoline in these converted automobiles, even though methanol has half the energy content of gasoline. We would expect engines designed specifically for alcohol fuels would be consistently more efficient.

To illustrate the effect of our recommendation, assume conservatively that 1.5 gallons of methanol will replace one gallon of gasoline. Since methanol contains half the energy content of gasoline (measured as Btu per gallon), the automobile consumes only 0.75 times as much energy to move one mile with methanol than it requires with gasoline. We propose that (in this example) 0.75 gallons of methanol be established as the quantity equivalent to one gallon of gasoline, thus accounting for the end-use energy efficiency of the methanol-fueled engine.*

The effect of this proposal would be to increase the CAFE average miles per gallon in proportion to the number of alcohol-fueled automobiles produced by a manufacturer. In the above example, if a manufacturer had a CAFE average of 27.5 miles per gallon on gasoline, and if that manufacturer then produced 10 percent of his composite production in pure methanol-fueled cars, his CAFE average would rise to 28.5 miles per gallon.**

## III. Discussion

Several aspects of our proposal require further discussion.

First, the legislative history of the applicable statute (P.L. 94-163) anticipates that you will determine equivalency "...on the basis of Btu equivalency of different quantities of various fuels, taking into account the energy required to process such fuels." Our proposal relies on Btu equivalency, but takes into account the relative efficiency of end-use for alcohol fuels.

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* - More generally, the equivalency factor would be computed by dividing the miles driven per gallon of alcohol by the ratio of the gasoline's energy content to the alcohol's energy content. Taking the energy content of gasoline at 20,200 Btu per pound, and of methanol at 9,800 Btu per pound, the exact calculation in the above example would be 1.5/(20,200÷9,800), for an equivalency factor of 0.73.

** - 90 percent of the cars at 27.5 mpg, and 10 percent at an equivalent of 36.7 mpg (27.5/.75).

We believe this approach is consistent both with the guidance in the legislative history and the intent of the statute to conserve energy in all forms.

We also believe, however, that it would be unnecessary and possibly unwise to adjust the equivalency calculation we recommend for the energy required to process gasoline from petroleum as compared to the energy required to produce alcohol fuels from coal or biomass. Aside from the computational difficulties involved, we offer three reasons for this view:

1. The chief objective of the statute and of current national energy policy is to reduce petroleum consumption. This objective would not be served by increasing process energy requirements beyond the savings at the point of end use for petroleum-based fuels. Thus, when evaluating petroleum-based fuels, the calculation of process energy requirements is useful precisely because of the overriding policy objective of reducing petroleum consumption.

   But petroleum is not (or should not be) involved in the production of alcohol fuels. Indeed, our proposal is intended to displace petroleum-based products with alcohol fuels made from coal or biomass. Since an abnormally scarce resource is not involved, ordinary economic evaluation is sufficient to assess the value of the energy inputs into alcohol fuels production. In other words, if alcohol fuels can be produced at a price lower than that of gasoline, they should be used. As we discuss later, we believe that alcohol fuels are economically competitive with gasoline.

2. Moreover, by displacing petroleum entirely, alcohol fuels save all the energy required to make gasoline, and do so with considerable leverage. Returning to the example used earlier, the effect of our proposal would be to displace at least one gallon of gasoline with 0.75 gallons of methanol. And, since two gallons of crude are required to produce one gallon of gasoline, the impact of our proposal on displacing imported crude oil is even greater.

3. Finally, the calculation of process energy might well render our proposal infeasible. There are a variety of ways to make alcohol fuels, each with different energy inputs. If the equivalency test depended on the value of these inputs, an engine designer would need not only to build an alcohol-fueled engine, but also to specify the process for making the fuel it consumes. This would be difficult at best, and since economics can be relied on to determine the fuel's value, unnecessary as well.

Second, we recognize that we are making our proposal before there is any consequential production of alcohol-fueled cars in this country, and indeed somewhat in advance of the availability of full test data. However, the purpose of our proposal is to stimulate the production of such automobiles, and so it must anticipate matters somewhat. It is thus important to separate two aspects of our proposal.

1. The concept of using end-use energy efficiency as the equivalency basis should be established now. This is the heart of the incentive our proposal offers, and we believe that sufficient test data are available to establish its validity.

2. The exact equivalency number need not be established now. Indeed, the actual energy efficiency of an alcohol-fueled engine depends on its design. The incentive to design more energy efficient engines is thus enhanced by defining the exact figures on a case-by-case basis, while establishing now the nature of the equivalency calculation.

Third, the equivalency test we recommend should be applied only to engines that are designed to work on alcohol fuels, and which would not run properly on gasoline. This requirement would prevent manufacturers from claiming the benefit of alcohol fuels for engines that could also run on gasoline, thereby nullifying the intent of our proposal. Such a requirement is both feasible and desirable.

1. It is feasible because alcohol-fueled engines are unlikely to run properly on gasoline. For example, alcohol-fueled engines gain efficiency by using higher compression ratios than are possible with gasoline engines, while still meeting nitrogen oxide emission standards. Similarly, these engines appear to require timing and choking characteristics that are incompatible with gasoline.

2. It is desirable to promote the design of alcohol-fueled engines using pure or nearly-pure alcohol, since maximum displacement of gasoline is thus achieved. The higher the proportion of alcohol used, the less feasible it is to use gasoline.

Fourth, our proposal does not presuppose your acceptance of alcohol as an automotive fuel under the provisions of the Clean Air Act. Indeed, much is gained and little lost by deferring these decisions until actual engines are built and

and data collected for your consideration. The advantage of this approach, of course, is to encourage the design of engines that are both fuel efficient and environmentally acceptable. Since currently available data suggest that the emissions of criteria pollutants are reduced in alcohol-fueled engines, we are optimistic that both energy and environmental objectives will be advanced by our proposal.

At the same time, deferral of these decisions does not compromise the requirements of the Clean Air Act, as a premature judgment might. We believe, however, that it would be useful for you to define with some precision the Clean Air Act requirements you would consider in evaluating alcohol fuels. This action, along with the action we propose, would establish the essential parameters for designing alcohol-fueled engines.

IV. National Benefits

Our proposal offers a number of benefits to the nation that will exceed the cost of attaining them.

From an energy perspective, the chief benefit is to open the way to the design of energy efficient engines that displace imported oil. National energy policy generally, and specifically the provisions of the applicable statute, clearly encourage these objectives. Without the end-use efficiency equivalency test - essentially miles per million Btu, rather than miles per gallon - the fuel economy standards program could lead in the wrong direction.

A related benefit is the impact of our proposal on the production of alcohol fuels. Alcohol fuels, whether ethanol or methanol, can be produced from domestic biomass and coal. National policy encourages the production of such fuels, and their production would be greatly stimulated by expanding the transportation markets available to them.

The other major benefit is the reduction of automotive emissions are improved by the use of alcohol fuels. Nitrogen oxide emissions benefit especially. And in diesel engines (a diesel fuel equivalent should also be established), the use of alcohol fuels overcomes the particulate emissions problem, which is becoming quite serious. In this connection, it should be noted that pure, or nearly pure, alcohol fuels do not have the high vapor pressures of blends. Thus, engines designed to run on these fuels avoid potential evaporative emission problems.

The costs incident to our proposal will be small in relation to the benefits. The proposal does not compel manufacturers to design alcohol-fueled engines. Rather, it offers an incentive to do so if the use of alcohol fuels is an economic way to meet the mileage standards. Thus, if our proposal results in new engine designs, it will be because the benefits of doing so exceed the costs of meeting the standards some other way.

In this connection, we believe that the use of alcohol fuels will prove economic. For example, we estimate that methanol can be produced from coal for less than $0.50 per gallon in today's dollars. If 1.5 gallons of methanol equate to one gallon of gasoline on a volumetric basis, then this methanol price is equivalent to a refinery gate price for gasoline of no more than $0.75 per gallon. And, because half the methanol price is to service fixed capital investment, methanol is insulated by at least half from the effects of general inflation, and totally from imported oil prices.

15 U.S.C. 2001(5) permits the Secretary of Transportation to include by rule any liquid fuel within the meaning of the term "fuel" if he determines that such inclusion is consistent with the need of the Nation to conserve energy. Since this action should proceed in parallel with your own, we have written the Secretary accordingly. A copy of this letter is attached.

We appreciate your attention to our proposal, and we are prepared to assist your consideration of it in any way.

Sincerely,

Robert W. Fri

RWF/ngs
enclosures

cc: The Honorable Charles Duncan
Secretary of Energy

ENERGY TRANSITION CORPORATION

ROBERT W. FRI, PRESIDENT
1101 CONNECTICUT AVENUE, N. W.
WASHINGTON, D. C. 20036
(202) 457-0868

May 5, 1980

The Honorable Neil Goldschmidt
Secretary of Transportation
400 Seventh Street, N.W.
Washington, D.C. 20590

Dear Mr. Secretary

The purpose of this letter is to propose that you initiate a rulemaking to include alcohol fuels as a fuel within the automotive fuel efficiency program. We are making this request in parallel with a request to the Administrator of the Environmental Protection Agency to establish end-use energy efficiency as the basis for computing the volume of alcohol fuels equivalent to one gallon of gasoline.

The intent of these requests is to provide an incentive to encourage the design and production of energy-efficient alcohol engines for automobiles. Our reasons for making the proposal are contained in our letter to the EPA Administrator, a copy of which is attached.

15 U.S.C. 2003(d)(2) empowers the Administrator to establish the equivalency test. 15 U.S.C. 2001(5) empowers you to include alcohol fuels within the meaning of the term "fuel" in the statute. It appears that complete implementation of our proposal therefore requires you and the Administrator to act in parallel. Thus, this letter and the letter to the Administrator should be viewed as part of a coordinated action.

The statute permits you to act if you determine that your action would be consistent with the need of the Nation to conserve energy. In particular, the legislative history indicates that improving fuel economy in motor vehicles can have a substantial impact on conserving petroleum.

We believe that our proposal to encourage the development of alcohol-fueled engines meet these tests. It appears that alcohol-fueled engines can be more efficient than gasoline engines in their use of energy; thus, energy is conserved overall. More specifically, alcohol fuels directly displace gasoline, thus having a substantial effect on reducing petroleum consumption. The attached letter discusses our proposal and its benefits in more detail.

We appreciate your attention to our proposal, and are ready to assist you in your consideration of it.

Sincerely,

Robert W. Fri

RWF/ngs
enclosure

cc: The Honorable Charles Duncan
Secretary of Energy

THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

JUN 17 1980

Robert W. Fri, President
Energy Transition Corporation
1101 Connecticut Avenue, N. W.
Washington, D. C. 20036

Dear Mr. Fri:

We acknowledge receipt of your letter of May 5, 1980, requesting the Department of Transportation to initiate a rulemaking to include alcohol fuels as a fuel within the automotive fuel economy program.

The National Highway Traffic Safety Administration (NHTSA) is responsible for the administration of the automotive fuel economy program and will handle your request as a petition. Our decision should be forthcoming in the very near future.

I appreciate your bringing this matter to my attention and your continued interest in the conservation of petroleum.

Sincerely,

Neil Goldschmidt

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 29 1980

OFFICE OF
AIR, NOISE, AND RADIATION

Mr. Robert W. Fri, President
Energy Transition Corporation
1101 Connecticut Avenue, N.W.
Washington, D.C. 20036

Dear Mr. Fri:

Thank you for your expression of interest in the question of the gasoline equivalency of alcohol fuels. From environmental, energy efficiency, and energy independence viewpoints, we agree with the purpose of your May 2, 1980 letter--the provision of appropriate incentives to develop engines able to use high proportions of alcohol. However, the specific approach that you recommend which would establish "end-use energy efficiency" as the basis for computing the alcohol fuel equivalent to gasoline seems too broad and, in fact, unnecessary.

While we agree that the energy content of a fuel should be one of the factors included in determining its gasoline equivalence factor, differences in engine efficiencies should be considered separately using the current EPA procedures for determining vehicle fuel economy. Since the fuel economy tests inherently measure and include differences in engine efficiencies this approach should yield approximately the same "gasoline equivalent" fuel economies as the "end-use" approach that you recommend. This approach would still provide a strong incentive for alcohol engine development without the complication of a new rulemaking action.

If it were assured, for example, that coal will be the primary source of automotive methanol fuel, it might be appropriate to give methanol an added benefit in its equivalency factor, due to the fact that petroleum-based fuel was being conserved by its use. This certainly would be in keeping with the intentions of EPCA. The actual determination of this additional benefit, if indeed appropriate, would appear to be quite complicated at this time and your further comment on this would of course be appreciated.

While we appreciate your request that EPA begin rulemaking action to implement an equivalency factor for methanol, the time appears to be premature since development of methanol engines upon which to base such an equivalency factor is at an early stage. At the present time, we have had no requests to certify a methanol engine for automotive use and, indeed, given the absence of a distribution system for methanol, the likelihood of such a request in the near future seems quite small.

Also, while we are extremely interested in methanol as an automotive fuel and are performing our own tests on dual-fuel diesels using 80-85 percent methanol, the fuels industry and indeed most of the government appears to be concentrating most of their efforts on synthetic crudes of one sort or another. This effort seems to be based on the relative energy efficiencies of these processes and the resulting fuel costs. If you or your clients have any information or data demonstrating the process efficiency or economic preference favoring methanol over these other fuels, we would be most interested in reviewing it.

As I mentioned earlier, we are interested in methanol use from both environmental and energy points of view and we certainly would like to see this fuel fully considered as a future transportation fuel. However, based upon the information we currently have, now does not appear to be the time to put substantial effort into a methanol/gasoline equivalency factor. Thank you again for your interest in this area.

Sincerely yours,

Michael P. Walsh

Michael P. Walsh
Deputy Assistant Administrator
for Mobile Source Air Pollution Control (ANR-455)

ENERGY TRANSITION CORPORATION

ROBERT W. FRI, PRESIDENT
1101 CONNECTICUT AVENUE, N. W.
WASHINGTON, D. C. 20036
(202) 457-0868

MEMO TO: Peter Hunt

FROM: Bob Fri

SUBJECT: MILES PER MILLION BTU PROPOSAL

DATE: January 8, 1981

You may recall that ETCO petitioned the Department of Transportation and the Environmental Protection Agency several months ago to accept methanol as a fuel for purposes of the Fuel Economy Act, and to revise the calculation of fuel economy from miles per gallon to miles per million Btu. Under the governing statute, the Department of Transportation is required to take the first action, and the Environmental Protection Agency to take the second.

After considerable delay, our petition to the Department of Transportation has been granted. A copy of the letter I received on this subject is attached.

I should clarify two points in the attached letter:

1. Acceptance of our petition means that the Department of Transportation will initiate a formal rulemaking to define methanol as an automotive fuel. We will have to complete this rulemaking procedure before the Department of Transportation can finally define methanol as an automotive fuel. Therefore, several months more of work will be involved.

2. The reference in the letter to the Environmental Protection Agency concerns a letter we received from EPA in response to our petition. In their letter, EPA stated that their current calculation of fuel efficiency was adequate to handle methanol. While neither we or the Department of Transportation believe that this is the case, the Department has elected to force EPA's hand by accepting our petition. Since the Department of Transportation must act before EPA in any case, the Department is taking the step necessary to get the ball rolling.

Although it has taken some time to get this far, I think the Department of Transportation is to be commended for supporting our petition. I will keep you informed of future developments.

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
WASHINGTON, D.C. 20590

JAN 6 1981

IN REPLY REFER TO:

NOA-30

Mr. Robert W. Fri
Energy Transition Corporation
1101 Connecticut Avenue, N.W.
Washington, D.C. 20036

Dear Mr. Fri:

This responds to your letter of May 5, 1980, to the Secretary of Transportation in which you request that alcohol fuels be included in the definition of the term "fuel" under 15 U.S.C. 2001(5), for automotive fuel economy standards purposes.

We have decided to grant your petition. Notwithstanding the decision of the Environmental Protection Agency not to initiate rulemaking now to establish an equivalency factor for alcohol fuels, we believe there may still be some benefit from including alcohol-fueled vehicles in the fuel economy standards program. This benefit would result if, as EPA suggests in their August 29 letter to you, their current test procedures yield approximately the same result as the "end-use" approach you recommend.

The granting of a rulemaking petition does not mean that a final rule will necessarily be issued. The determination of whether to issue the rule you requested will be made during the course of the rulemaking proceeding, in accordance with statutory criteria.

Sincerely,

Michael M. Finkelstein
Associate Administrator
for Rulemaking

cc:
Mr. Michael Walsh
Environmental Protection Agency

LITTON INDUSTRIES 490 L'ENFANT PLAZA EAST, S.W., WASHINGTON, D.C. 20024

WALTER P. LUKENS, DIRECTOR-WASHINGTON OFFICE
(202) 554-2570

December 24, 1980

Mr. Peter S. Hunt
Research Analyst
Subcommittee on Energy and Power
House Interstate and Foreign
Commerce Committee
Annex 2, Room 3302
Second & C Streets, S. W.
Washington, D. C. 20024

Dear Mr. Hunt:

I found your Methanol Policy Hearings to be not only informative but also of great interest.

We would appreciate your consideration for inclusion in the Record, the attached statement and brochure, copies of which were provided prior to the hearings.

Sincerely,

Walter P. Lukens

Walter P. Lukens
Vice President

WPL:geg

Attachments

# MEMORANDUM IN SUPPORT OF 10 PERCENT ENERGY TAX CREDIT FOR METHANOL PRODUCING BARGES BUILT IN U.S. SHIPYARDS

## I. Summary of Proposal And Rationale

### A. Energy Credit For Methanol-Producing Barges

An additional 10 percent energy tax credit should be provided for the construction in the U.S. of "methanol producing barges" which will be barge-mounted processing plants that can be taken to offshore sites in the oceans and used to convert the huge untapped world supply of natural gas from offshore* oil and gas wells into liquid methanol. This gas is presently being wasted by flaring or is "locked in" the well because it cannot be economically transported, in a gaseous state, to an on-shore facility.

### B. Potential Energy Impact of Barges

The potential increase in energy supplies from these processing barges is enormous. It is projected that by 1990, 50 to 100 of the methanol producing barges could be in commercial operation. The annual production of methanol from 100 processing barges would be 27 times the total U.S. consumption of methanol in 1979. Expressed in Barrel of Oil Equivalents, this additional supply of methanol is equal to 15.2 percent of U.S. oil imports in 1979 and 6.9 percent of total U.S. oil consumption in 1979.

*/ The barges may also be used to recover gas from some wells which are actually located on shore relatively near the waters edge. For example, the barges might be towed up large rivers, in various locations around the world, to reach wells which are otherwise inaccessible to processing facilities. Such wells are substantially the equivalent of off shore wells, and for purposes of this memorandum no distinction is made.

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Much of the additional supply of this liquid fuel will be available in the mid-1980's when a dozen or so processing barges could be in operation, with the number of processing barges increasing rapidly in the second half of the decade.

The principal use of methanol in the years ahead will be as a substitute for or additive to gasoline. The production of methanol from 100 processing barges is equivalent to 16.2 percent of the total U.S. consumption of gasoline in 1979. The substantial near-term increase in the supply of methanol from these barges will accelerate technological modification to permit the full use of both methanol and domestically-produced ethanol in the transportion sector.

The three major U.S. automobile makers recently announced that, given only one year's lead time, they could produce automobiles powered by either methanol or methanol-gasoline blends.

C. <u>Positive Impact on the United States Economy From Construction of Barges</u>

The construction in U.S. shipyards of 10 methanol producing barges per year in the 1980's would create approximately 50,000 jobs, of which 17,500 jobs would be direct employment in U.S. shipyards and 32,500 jobs would be indirect employment with suppliers and others as a result of the increased economic activity. The 17,500 direct jobs in U.S. shipyards are equal to 17.9 percent of the average production employment in U.S. shipyards in 1978. Without the 10 percent energy tax credit to offset foreign government shipbuilding subsidies, it is doubtful whether significant numbers of the processing barges (beyond the initial prototype which may be completed in the U.S. in 1983) would be built in domestic shipyards.

D. Conclusion

Until methanol becomes readily available from U.S. coal and biomass resources, the expanded supply of methanol in the international market will be of great importance to the United States in fulfilling this country's identified demand. Thus, a 10% energy tax credit for the construction of these barges is justified not only by the benefits of gaining access to an enormous, presently untapped resource of energy, but also by the desirability of increasing employment in U.S. shipyards, as well as sustaining U.S. ship construction capability in support of defense requirements.

II. Background

A. An Untapped Energy Resource

At present, billions upon billions of cubic feet of natural gas are flared from offshore oil and gas wells or "locked in" awaiting an economic means of exploitation. Thus, much offshore gas, like shale oil, is a present, major untapped resource of energy that could be of tremendous benefit to the United States if it could be economically produced. At present, efforts are being made to extend undersea pipeline technologies to recover more of this gas. However, such technology is not likely to become economical for many offshore sites. The methanol barges provide broader recovery possibilities than LNG and methanol's low volatility would avoid the objection raised against LNG's transportation and delivery. The mobile nature of the processing barges makes low-yield wells economically recoverable which would not be commercially practical by alternate methods. As methanol can be transported without special handling in conventional tankers, its economic advantages are further enhanced, particularly with reference to resources which are commercially unproven, of low-yield or remote to a supporting infrastructure. Therefore, this innovative approach can unlock and will make available energy more quickly than other alternatives.

B. Methanol Producing Barges: An Innovative Solution

Large barge-mounted processing plants can be used to convert currently unavailable offshore gas into methanol, an alcohol fuel that can be transported safely and used in a variety of energy applications. The methanol would be produced by an existing process that has been proven in numerous land-based plants. The barge-mounted plants would take on gas produced by the offshore wells and off-load the finished methanol directly into tankers for transport to the point of use. These mobile processing vessels would be documented under U.S. laws and make available energy from existing, but non-producing, stores of gas.

Perhaps of equal importance, if a particular gas supply terminates through exhaustion or foreign intervention, the vessel's mobility would enable it to move to other available gas resources, thus preserving the immediate ability to produce energy as well as protecting the capital investment itself.

C. Methanol: The Emerging Energy Fuel

Methanol is today the sixth largest volume U. S. organic chemical. While the utilization of methanol by the chemical industry will continue to rise at a steady level, its use as a transportation fuel will accelerate rapidly as the available supply increases.

Used by itself as a fuel in gas turbine or specially modified piston engines, or in mixture with gasoline as an octane-boosting additive, methanol can be of great value in providing an alternative to premium petroleum-based fuels. It can be used (1) as a blending component for oil based gasoline, (2) as a base from which gasoline is produced, or (3) by itself as an unblended fuel. At present, gasoline blends with up to 15 percent methanol have been used in taxi and other specially-modified fleets in several foreign countries. Both methanol and ethanol gasoline blends ("Gasohol") will be accommodated by vehicle design changes and either of these fuel blends can be used in slightly modified present engines and fuel systems. In Brazil, cars are being produced to run on 100 percent ethanol. In this country, the EPA has approved Sun Oil's "Oxinol," a mixture of 95 percent gasoline, 2.75 percent methanol and 2.25 percent tertiary butyl alcohol, which is now being successfully test marketed in Florida. As previously noted, all three major domestic automobile manufacturers agree that adequate technology exists to produce methanol- powered vehicles in this country given a one-year lead time.

Ford Motor Company is currently testing a methanol-powered automobile. When a methanol supply is assured, the commercial production of these relatively pollution-free vehicles will commence. Although the gasoline engine will not be totally supplanted, the emission problems of methanol can be more easily solved and overall air quality will be improved.

Although methanol can be produced from domestic coal and biomass, production from these sources will largely be constrained through the 1980's by the long-lead time and huge capital sums necessary to construct new facilities. While methanol has immediate transportation application as an additive to unleaded gasoline, the large scale use of methanol as a "neat" transportation fuel (100% methanol) will evolve as the result of new investments for the required modification of automobile engines. To provide an impetus for this investment, there must be a substantial program to guarantee that adequate methanol supplies will be available. The production capacity of the methanol barges would insure an early and significant supply of this transportation fuel. The output of the barges would substantially accelerate the development of an alcohol technology and markets in which American coal and biomass from American farms and forests would play a major role.

Clean burning methanol, which can be utilized in existing gas turbine engines without modifications, has a particular benefit for utility companies. Methanol used for peak-power requirements lowers the overall emissions of the facility and helps the utility company meet existing Environmental Protection Agency standards.

D. Barges' Benefits for United States Economy

The barges will, in essence, be floating methanol factories.

Each barge will be nearly 4 acres in area, will take almost two years to construct, and will cost about $300 million to build. In addition to the necesssary processing and storage equipment, the barges will contain quarters for a substantial crew. One indication of the barge's size is that it will displace 44,000 tons which approximates in size the World War II Essex class aircraft carrier.

With the availability of an energy tax credit, */ the processing barges could be built in the United States, and this country would take the lead in an emerging multi-billion-dollar industry of world importance. A potential market exists for 50 to 100 processing barges to be built during the 1980's, with up to ten barges being built per year. Several shipyards in the U.S. are capable of building more than one processing barge per year. For example, the Ingalls Shipyard in Mississippi estimates that it has existing capacity available to build four per year. The manpower required to construct four barges per year at Ingalls would be 6 to 7 thousand. Using a conservative ratio of 1 to 1, an additional 6 to 7 thousand jobs could be created in the surrounding communities. In addition, employment would increase in the steel-making and other supplier industries, and in the communities around them. In all, it would not be unreasonable to expect that, if ten barges per year are produced in the United States, total U.S. employment could be increased by 50 thousand jobs. Additional benefits would include increased government tax revenues, and decreased needs for social services and transfer payments.

*/ In view of lower shipbuilding costs in foreign countries, a credit is needed to give an incentive to U.S. production. See discussion below.

The benefits of domestic construction are further emphasized when compared to the potential of this multi-billion dollar industry being entirely foreign. Unrealized U.S. ship construction jobs, non-utilization of U.S. material supply, relinquishment of any U.S. control relative to methanol distribution, and the export of U.S. dollars to acquire the processing barges (rather than the converse) would result in lost opportunities of major proportions to the U.S. economy and further erode our efforts to attain a favorable trade balance.

E. Higher Costs of Construction In the United States

Offshore gas recovery barges can be built in a number of countries other than the United States, including Japan, Korea, Germany and Sweden. The foreign yards often experience lower costs for both manpower and materials. These advantages, as well as direct and indirect construction and financing government subsidies, effectively eliminate U.S. shipyards in competitive procurement.

These substantial disadvantages to U.S. shipyards are partially restored by current maritime laws which provide loan guarantees and construction differential subsidies for vessels built in U. S. shipyards. However, the applicability of these benefits, and the annual appropriation of funds for their use, is severely limited.

Even if the first methanol producing barge is built in the United States, once its potential is proven, the worldwide competition could be expected to become intense. Without an energy tax credit, it is unlikely that very many, if any at all, of the future barges would be built in the U.S. To the contrary, it is likely that the present foreign competitive advantages would result in the great bulk of the barges being built abroad.

F. Mutuality of Public and Private Interests

Although the methanol producing barge project will require a multi-billion dollar investment by private business interests to become a reality, the prospects of profitable operation appear reasonable. As previously noted, the gas resources exist, the conversion process is proven, and safe transportation is assured.

Because the world's gas resources are more widely dispersed than the world's oil supply, the U.S. public has a definite interest in the development of methanol as an alternate transportation fuel. Much currently locked-in gas is located in non-OPEC nations which would provide energy importers such as the United States not only with increased supplies of energy but also with more sources of supply. The public would benefit from the increased supply's dampening effect on price increases as well as supply diversity providing more protection from OPEC embargoes.

The major benefits to both the public and private interests will not grow in steady increments as each processing barge is placed in operation, but will be realized when the automobile manufacturers have responded to the assurance that methanol's ready availability permits general production of a methanol-powered automobile. This time can be advanced by the adoption of the proposal advanced herein. An energy tax credit would not only improve the risk-reward ratio of the methanol barge as a

U.S. project, but, quite importantly, it would serve as a declaration of public support encouraging the development of methanol as a fuel source and thereby provide the necessary signals to speed development of means for its utilization.

All operating risks would remain with private business. However, investment of private industry in the processing barge will directly benefit the public as a whole, both in assuring the United States a preeminent position in a newly developing industry but also in the long-term extension and protection of energy sources. Under such circumstances, public participation in the investment burden via the energy tax credit is a warranted and reasonable exchange.

III. A 10 Percent Energy Tax Credit Is Justified On The Ground Of Energy and Other National Policies

Not only will the credit help to provide substantial employment in U.S. shipyards, it will help the U.S. companies (and, therefore, the United States) obtain and maintain control over the major, new worldwide energy development process which is signified by the methanol producing barges. Conversely,even though U.S. companies could purchase barges built in foreign shipyards and in that way participate to a degree in this new methanol energy development, dominance by foreign shipyards increases the likelihood that the tapping of new world-wide energy gas supplies would be influenced by foreign companies and, indirectly, by foreign governments.

Although the United States is currently the world's largest consumer of chemical grade methanol, using approximately 30% of the world's production, it now supplies its own needs. However, as methanol becomes accepted as a fuel or fuel additive, demand may well increase exponentially and greatly exceed projected world production capacity. Methanol from coal and biomass resources cannot possibly meet the demand for methanol during the remainder of this century. Thus, to serve its own interest, the United States must encourage the increase of the total world supply of methanol by assuring rapid implementation of the methanol barge program.

The methanol produced by the processing barges would move freely in the world market, increase availability in the United States and exert a beneficial pressure on world prices. Moreover, a major increase in the supply of methanol would stimulate new applications and markets, and new investment in current technology, for not only methanol, but also ethanol from domestic sources.

The energy tax credit for methanol producing barges is based on the same fundamental policy considerations which underlie the energy tax credits that are presently available. Under current law, energy tax credits and production credits have been provided for investments in equipment which will increase the production of conventional forms of energy -- oil and natural gas from unconventional sources. For example, an energy tax credit is available for equipment to produce natural gas from geopressurized brine and for equipment to produce oil from oil shale. These credits are provided in recognition of the fact that oil and gas which are inaccessible using traditional means of production and marketing can make a significant contribution to the total available supply of energy, and that the production of oil and gas from these unconventional resources should be encouraged.

Like oil shale and geopressurized brine, offshore gas could make a substantial contribution to the total supply of energy, but is inaccessible by traditional means of production and marketing. Like the credits that are available under current law, the proposed credit, by reducing the cost of the methanol producing barges, would substantially increase the likelihood that offshore gas will be recovered and made available to the energy-consuming public. Thus, the tax credits that are available under current law for the production of oil and gas from unconventional resources are a precedent for the proposed credit for offshore methanol producing barges.

Equally important, the proposed credits would put the United States in the lead in an emerging technology that has the potential of becoming a multi-billion-dollar industry with worldwide application. The credits would thus promote investment in what is potentially a major industrial "winner" combining a high degree of technological and engineering innovation with the promise of thousands of American jobs over an extended period.

A BILL

To amend the Internal Revenue Code of 1954 to provide a 10 percent energy tax credit for methanol processing vessels.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled that:

(a) IN GENERAL.--The table contained in clause (i) of section 46(a)(2)(C) of the Internal Revenue Code of 1954 (relating to energy percentage) is amended by adding at the end thereof the following new item.

| | | | |
|---|---|---|---|
| "VII. METHANOL PROCESSING VESSEL.- Property described in section 48(l)(17) | 10 percent. . | .Jan. 1, 1981. . | .Dec. 31, 1990 |

(b) DEFINITION.--Section 48(l) of such Code is amended by redesignating paragraph (17) as paragraph (18) and by inserting, after paragarph (16), the following new paragraph.

"(17) Methanol Processing Vessel.--

(A) In General.--The term 'methanol processing vessel' means any integrated facility consisting of a vessel and the equipment it supports and houses which is used--

(i) to process natural gas into methanol, and

(ii) temporarily to contain or store methanol incident to processing.

(B) Exclusion Of Drilling And Production Equipment.--The term 'methanol processing vessel' does not include equipment to drill wells or to produce oil or gas.

(C) Exclusion Of Vessels Constructed Outside The United States.--The term 'methanol processing vessel' does not include any vessel constructed outside the United States."

(c) TREATMENT AS ENERGY PROPERTY.--Subparagraph (a) of section 48(l)(2) of such Code (defining energy property) is amended by striking out "or" at the end of clause (viii), by inserting "or" at the end of clause (ix), and by inserting after clause (ix) the following new clause.

"(x) methanol processing vessel."

(d) EFFECTIVE DATE.--The amendments made by sections (a), (b), and (c) shall apply to taxable years ending after December 31, 1980.

Litton WESTERN GEOPHYSICAL

10,001 Richmond Avenue P.O. Box 2469, Houston, Texas 77001
Telephone 713 789-9600 Cable WESGECO Telex 762406

Carl H. Savit, Senior Vice President, Technology

January 13, 1981

The Honorable John D. Dingell, Chairman
Interstate & Foreign Commerce Committee
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

As a consequence of discussions with Committee staff, Litton Industries, Inc., desires to submit the following statement concerning its plans for establishing a supply of methanol fuel:

In today's world of energy shortages and ever-increasing energy prices, a prime energy source is being totally wasted in scores of locations around the world. That crucial energy source is natural gas. Every day, about 20 billion cubic feet of natural gas--the equivalent of 3 million barrels of crude oil--is being flared into the atmosphere, while still other reserves are located too far from a pipeline or market to be economically recoverable now or in the foreseeable future.

Litton Industries has undertaken a program to recover much of this flared or unused natural gas. Through its subsidiary companies, Litton Energy Systems of Houston, Texas, and Ingalls Shipbuilding Division of Pascagoula, Mississippi, Litton plans to construct and operate a series of barge-mounted chemical processing plants which will convert the wasted or locked-in reserves at the offshore gas wells to an efficient alcohol fuel--methanol.

A typical methanol plant, anchored in deep water or ballasted to the ocean floor in shallower water, can convert about 100 million cubic feet of natural gas per day to about 1 million gallons of methanol. The methanol is stored on board the barge and periodically transferred to a tanker for transport to world markets. If the natural gas supply is depleted or becomes otherwise unavailable, the plant can simply be moved to an alternative location.

To capture and use the world's presently flared natural gas would require more than 150 of these barge-mounted plants. Building the barges will require a major effort on the part of the United States and many other industrial nations. Output from the barges will generate a new $50 billion/

year industry with worldwide impact on terms of methanol supply, production, and use. This new major industry will enable the U.S. to capitalize on its technological leadership by integrating proven chemical processing systems with mass-produced U.S. -flag barges. Through early domination of the worldwide market for methanol barges, the U.S. will control a major new and cost-effective liquid energy supply. Since the economic and technical practicalities of the methanol conversion barges are established, there is no need for government funding of research and development. Markets for methanol are rapidly expanding based on its demonstrated use in the power, automotive, and chemical feedstock sectors.

A recent Commerce Department report states that barge-mounted methanol conversion plants anchored in U.S. coastal waters could provide an economical source of fuels and revitalize the ailing U.S. shipbuilding industry. In addition, the Department estimated that the international market for methanol will soar from 11 million metric tons/year in 1979 to more than 27 million annually for methanol by 1990.

Thus, today, the U.S. has the opportunity to take an active leadership role in this emerging multi-billion dollar industry. The benefits to U.S. suppliers of equipment and to the shipbuilding industry would be enormous. Many thousands of jobs would be created throughout this country. It has been estimated that construction in U.S. shipyards of 10 methanol barges per year in the 1980's could create approximately 50,000 jobs--17,500 of which would be directly in the shipyards, while another 23,500 would be created in support of that activity.

Need for Government Support

In order to assure U.S. participation in the methanol barge world market, mechanisms are needed that allow for successful competition with foreign shipyards. It is an established fact that foreign governments assist their industrial sectors through a variety of tariffs, subsidies, tax incentives, and even direct investments.

Thus, it is important that the U.S. recognize the need for government support of methanol barges if this country is to initiate a new industry and maintain its leadership position in the world marketplace.

Sincerely,

Carl H. Savit

CHS:ba

[Whereupon, at 3:40 p.m., the hearing adjourned.]

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