THE DIRECTION FOR SYNFUELS R&D

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This final panel is composed of representatives from each of the major sectors represented in the first two days of the conference, i.e., federal, military, industry, and university. Individual panelists were invited to present any specifics which they might wish relevant to the theme of the conference and in addition to comment upon any and all areas which were discussed (or which were not discussed) at this conference. No preprint, handout, or visual aid materials were required; the entire session was tape-recorded and edited, accounting for the conversational style herein.

INTRODUCTORY REMARKS

R. D. Fleming
DOE-TEC

The purpose of this final summary panel is to provide an opportunity for representatives from government, industry and universities to summarize the results of this conference and to recommend the direction for synfuels R&D and to comment on how this R&D may influence their particular segment of industry.

The members of the panel are: Dr. D. W. Brinkman, Bartlesville Energy Technology Center of DOE; Dr. W. F. Taylor, Exxon Research and Engineering Company; Dr. J. A. Paraskos, Gulf Science and Technology Company; Mr. D. F. Ryan, Exxon Research and Engineering Company; Mr. J. M. Colucci, General Motors Research Laboratories; Mr. R. E. Baker, Ford Motor Company; and Dr. R. K. Pefley, University of Santa Clara.

We should note that Mr. E. E. Ecklund was originally scheduled to participate on this panel. However, since Mr. Ecklund will have an opportunity to provide closing remarks later this morning, he will not participate on this panel. Because we have had very few comments in the conference regarding coal liquids, I have asked Mr. D. F. Ryan to take Mr. Ecklund's place on the panel and to speak about Exxon's work on coal-derived fuels. Dr. Brinkman will lead off the panel discussion.

SUMMARY PRESENTATIONS

D.W. Brinkman (BETC):

I would like to make a couple of general observations and then cover government research programs. An outsider observing this conference for the last couple of days would probably go away shaking his head. He would probably be reminded of the blind people describing different parts of the same elephant. We get quite a few views coming out of here. To us, that is understandable. We all have our own viewpoints and opinions and backgrounds. Occasionally, we find ourselves arguing about whether the glass is half full or half empty, I think. That is understandable too, probably because sometimes you have to justify funding. I know all year long we are talking constantly about how much progress we are making, but towards the end of the year when it is funding time, we maintain that there is an awful lot of research that needs to be done. So that is understandable too.

The second impression I get is a kind of a swarming motion. We are all going different directions at the same time at different velocities. Now technically, that is also understandable. It is, actually, probably very sound. There is obviously no overwhelming agreement, no one direction that everybody says we ought to be going, and so we are really only covering the basics. Well, that is great. That is sound, technically. But politically, it is probably suicide. It is very difficult to get any coherent program going, any push, any real motion headed in any one direction when there isn't some consensus as a background. And so, all this turmoil that we have heard about over the last two days is understandable. We all realize it and appreciate it, but it is going to cause some problems.

Within DOE, several groups are looking at research relating to what we have been discussing. The Pittsburgh Energy Technology Center is looking at coal liquefacation, trying to provide some basic data, some possible help in what we call high-risk research.

LERC is looking at shale oil, evaluating different processes.

At BETC, we have one group which does nothing except look at fuels and engine systems, looking at the fuels and the engines together. Unfortunately, this is the one group right now that is having the most trouble getting funding. In fact, a couple of weeks ago they had -0- dollars for the fiscal year 1979. There are problems like that in every research group, but that gives you some idea of where we are. The very group that we feel within this room that needs the most funding is having trouble just paying salaries. I happen to be working on a project looking at fuel stability. I mentioned that at the workshop a couple of nights ago. Again, trying to provide some basic data both on petroleum fuels and synthetic fuels, looking at mechanisms and things that a lot of companies might not look at for the mere fact that it is not going to return too many bucks, at least not directly. But we are trying to provide some data that we hope is of interest to you. I am looking at some of the synthetic fuels that we have been producing in the last few years and looking at petroleum-based fuels. It is difficult to get a major program going in the government. I think most of you can appreciate that. We work on a year-to-year basis, where as in industry, it is possible to set up a program and fund it for years at a time. In DOE, everything goes from year-to-year, and depending on who happens to be in power in Congress, who happens to be in control of the White House, who happens to have the Departments' ears, that's who gets funded that year. And so, it is very difficult to get an ongoing program set up within the government. Now, we are doing a total reorganization, trying to shift away from inhouse research within DOE and getting in much more into the project management type research where the funding goes to DOE, but most of the work goes out to industry, and research institutes. We hope that most of our reorganization activities are behind us, and that now we can have some kind of a coherent direction which will provide the needed research.

W.F. Taylor (Exxon):

From the comments made here at the meeting, it would appear clear that the obstacles

to the establishment of a commercial synfuel industry in the United States are primarily nontechnical in nature and involve environmental and economic considerations. Nevertheless, it would appear prudent in the meantime that we technologists proceed with the necessary R&D to prove the technologies which would be necessary for the commercialization of a syncrude-containing fuel. This will allow us to, first, minimize the uncertainties associated with the transition to synfuels and also provide us with the opportunity to develop more energy- and cost-efficient and environmentally acceptable technologies in the future.

Thus, there is an obvious need for the development of synthetic fuels. Again, for that time petroleum supplies alone will not be adequate for our needs. In addition, we must be concerned now about developing alternatives. Thus, there is need to proceed promptly with research and development in this area so that technology which will be necessary for the commercialization of a synfuel industry will be ready in time.

In my opinion, synfuel research and development should be broad and imaginative in scope and fundamentally based. For example, synfuel R&D should address the question not only of current specification fuels, but also modified and or broadened specification fuels. Some other examples of key questions which should be addressed include:

(1) How can increased supplies of synfuel be used optimally in conjunction with diminished supplies of petroleum?

(2) How can the overall transportation system be optimized for maximum energy efficiency, including not only syncrude production but the refining and upgrading and selection of finished fuel properties, powerplant characteristics, vehicles and also the critical supporting technologies that work in this system (and I will cite an example of that—lubrication technology)?

J.A. Paraskos (Gulf):

I would like to speak to you concerning what I think the major forces acting on the refining industry are going to be, what the impact of those forces will be, and the role I feel that synthetics from coal and shale will play as a new term in the energy equation.

Let us start by taking a good look at where we are today. The refining industry and Detroit have tremendous capital investments; it would be folly of the worst kind to walk away from these investments. I don't think, from what I have heard in the past three days, that we could; and I think that is good. I believe that Detroit would like to continue to make internal combustion engines and would like to get into the diesel car; I think that the refining industry would like to continue to make gasoline, diesel fuel and jet fuel. New engines may come about, but I don't think we are going to see too much along this line before the year 2000. So we can then presume that the refineries are going to be trying to make gasoline at about the same volumes, if current projections hold; and if diesel automotive legislation doesn't stop it, there will be an increasing amount of diesel fuel and middle distillate fuel for the motor car being produced by the refineries.

At the same time, the demand for residual fuel oil is probably going to increase somewhat in the next few years and then start to decrease, if logic holds, because of the incoming coal and nuclear power industries. In the face of decline and demand for residual, U.S. refiners are going to be faced with another very serious technical challenge before we get to the point where they are going to be very seriously worried about shale and coal liquids. This is going to be the coming crunch in poor petroleum feedstocks.

I think that the new-term feedstocks are going to become dirtier and they are going to become heavier. They are going to contain more residual. They are going to contain less naphtha which makes gasoline, and they are going to contain less middle distillate which makes diesel and jet fuel.

I believe this will occur because of two reasons: primarily because the Middle East is going to go into the refining and petrochemical business in what looks like a big way, and they are smart people. They are going to want to keep the light, low-sulfur feedstocks for themselves and refine those and sell finished products. Furthermore, as we get to a point where crude begins to run out, we are going to start using more and more of what the world has most of, namely heavy, dirty, sour

crude. In spite of this, I believe the price of crude is going to continue to increase. Eventually, the price of crude is going to intersect the price of synthetics from coal and shale, they say. Even if that happens, I don't know whether the refining industry is going to want to put synthetic crudes, whole crudes into their refineries. I think they will sidestep that and try to put the dirtiest kind of petroleum into their refineries before they start putting whole synthetics into their system.

Then, selective fractions of the synthetics will probably start coming into the refineries. For example with coal liquid, about 30 percent of the yield of liquid products from a synthetic liquid material being made from the coal is about the same boiling range as the naphtha which goes into making gasoline. This material may be pretreatable and reformable into high-octane, high-quality gasoline. With shale oil, the naphtha may be refinable to gasoline, diesel, and jet fuel. The thing that is important to note, though, is that we probably will want to do this in existing refineries. We will probably want to utilize the capital that we have. And so, the question is: how do you do what you want to do first with the pressure, temperature, space velocity, and catalyst requirements that you need to have in the future? And that is one of the key areas that has to be addressed in the near future.

What do we do with the rest of the synthetics? Well, I have heard it over and over again, and I don't know whether it catches hold, but I think the synthetic bottoms are going to go into utility fuels. This is going to push more and more residual into the refinery's throat, and it's going to have to deal with it; the refinery will want to deal with that rather than the synthetic residual. Eventually, however, I am sure that as the crude begins to run out (probably post-2000), the refinery will probably have to start pulling synthetic crude totally into its refineries. Where this synthetic crude is going to be made is up in the air. I think that there is a question as to whether it should be done at a synthetic fuel plant or whether it should be done at a refinery. There is a point to consider, however, as the refinery gets more and more needs to process these heavier, dirtier residuals, it is going to evolve towards the point where he can look at the shale- and the coal-derived liquids in a much more intelligent way. Catalyst evolution will have to take place in order to upgrade these materials. I think that is where a lot of the R&D should be done.

In addition, hydrogen requirements for refineries are going to increase tremendously. Dr. Uyehara recognized this in one of his slides. I think that we know that coal liquefaction requires hydrogen. The most intelligent place from which to get future hydrogen is coal. If we are going to be building Texaco pots units or corporate pots units or hydrogen-producing units from other sources, then maybe it is a good time to consider where to put that coal liquefacturing process. Maybe integrated liquefaction and petroleum refining is not such a bad idea when you look at the post-2000 time frame. Maybe the smart move is to put that liquefaction facility near a refinery to take advantage of its distribution system. Let hydrogen production from coal take place at the refinery to help with the heavier and sour crude. In any case, I don't think these questions have been resolved; if you put a coal liquefaction site near a refinery, you run into trouble transporting coal, but I think that we have to take an economic look at this problem to find out where to spend our money most intelligently.

In summary, I think R&D is needed to address the short-term issues of refining selective cuts of coal- and shale-derived liquids in new or existing plants in order to determine the magnitude of catalyst and processing improvements required to produce the gasoline and diesel fuels that we anticipate. However, it appears that the approach is going to be evolutionary and not revolutionary. If we are presently addressing the refining of future crudes (which are getting worse and worse), it may be that the transition to refining whole synthetics will not be as painful as we seem to think. But much work is needed.

I want to say in conclusion that we have got to get on with it. We have to start building some plants because we are running out of crude.

D. Ryan (Exxon):

I plan to present some yields that we obtained from the Exxon Donor Solvent liquefaction process and to highlight the quality of these liquids and the types of tests that have been run on them

and some of the conclusions that we have reached so far.

The Exxon Donor Solvent process produces about 2.7 barrels of liquid product per ton of dry coal. There is some variation in the yield, depending on the severity. Breaking the liquid down into a naphtha of 350 to 650 distillate in a 650+ gas oil, typical yields are as follows:

- Naphtha — 37 weight percent
- 350 to 650 — 24 weight percent
- 650 plus — 39 weight percent

Depending on severity, for example, the naphtha could vary from 25 to 55 weight percent. At the higher yield, of course, the distillate gas oil yield could be backed off.

The naphtha is very aromatic and highly naphthenic; it is very low in paraffins (roughly 12 percent). This naphtha can be hydrotreated in a single stage (conventional petroleum hydrofiner) to meet catalytic reforming specs. In a conventional reformer, we can achieve 90 liquid volume percent yield at 100 octane and about 85 liquid volume percent yield at 104 research octane clear. In addition to the high yields of high octane naphtha, there is a net production of hydrogen of about 2000 standard cubic feet per barrel of naphtha produced. This naphtha, once hydrofined, is probably the best reformer feed that I have seen.

Regarding the distillates: we have run tests on the 350 to 650 fraction in a home after-burner. This fuel (as it comes out of the EDS process) meets No. 2 fuel specs except for the gravity. There is a 30 API gravity spec on No. 2 fuel. We are well below this. Other than that, this material burns well in the tests that we have run. We have also looked at a nominal 350 to 700 distillate cut that was sent to Westinghouse for a stationary turbine combustion test that was sponsored by the Electric Power Research Institute. At this time, I really can't give you too much in the way of data on how this material performed. It was the lowest NO_x emitter of all the coal liquids that were tested, consistent with its low fuel-bound nitrogen content. We have also tested 400+ fuel oil fractions in a 50-horsepower boiler.

Regarding smoke emissions: these fuels were as good or better than either a low-sulfur fuel oil or a regular sulfur fuel oil tested side by side.

Regarding particulates: the coal liquids were lower than the petroleum test fuels.

PNA's were within the range of petroleum experience. Our technology department suggested that we burn a greater quantity of this fuel to get better PNA measurements, so I want to reserve final comments about PNA's at this time.

NO_x was high. For the particular fuel tested, the NO_x level was about 580 PPM which (compared with the new source performance standards) are up 225 for oil and about 500 for coal. We do have a problem with the NO_x emissions. The fuel tested, however, was a direct product of the EDS process. It was not hydrotreated in any way to reduce nitrogen.

That concludes my comments on the yields and the types of tests that we have run.

Basically, I have heard an awful lot about coal liquids as being dirty and sinful and what have you. In many ways, they are as good, and, in some ways, better than some typical petroleum streams that are processed today.

J.M. Colucci (GMRL):

I would like to say that my talk is a "well-rehearsed" talk, not that I have rehearsed it many times, but in the course of the two days of this conference, many of the things that I have intended to say have already been said. But I think the theme that is running through here is still an important one regarding energy conservation of the resources that we are going to have to use. I would like to continue with my comments because I think they are important to the whole issue.

In 1975, GM Research had a symposium on future automotive fuels which many of you attended. At that symposium, we indicated that we were interested at that time in doing work which would result in maximizing the overall energy utilization efficiency of this system. I am talking about "resource" from in the ground through all the steps winding up with the end use. This system seemed to provide significant opportunities for energy savings as our nation shifted its transportation needs from a petroleum-based economy to an economy based on coal, oil shale, or even biomass. The interest is obvious, we want to maximize miles per ton of material mined or per ton of material farmed. Inherent in this concept is the assumption that to achieve the energy savings in any one of the intermediate steps, the end user may

have to change his system and, in many cases, even decrease the energy utilization efficiency in his step. We at GM were and still are interested in doing this kind of research. In fact, we even proposed this to the Fossil Energy Branch of the Department of Energy.

But first, let us concentrate on the synfuels R&D that results from this type approach. The major contrast to using less-refined fuels from coal or oil shale is to use gasoline and diesel fuel from these sources which meet current fuel specifications. Many fuel suppliers have already concluded that this may be the route to follow. However, we at GM believe that it is too early to make that decision, especially since we have not had the opportunity to evaluate the potential energy savings. Another point is that we still have time to make this evaluation. Petroleum is not going to run out tomorrow. I think we are going to have petroleum-based systems at least until the end of this century. So we do have time to look at these other resources.

Another consideration is that doing work on this type of a concept will provide all of us with interesting and challenging R&D opportunities which we necessarily won't get if we assume we are going to make current spec fuels from coal and oil shale.

In obtaining future transportation fuels, let us try to take advantage of the inherent properties of coal- and shale-derived liquids rather than expending considerable energy to convert them into fuels which match fuels and petroleum. I think many of the other speakers have also emphasized that point. In order to assess the potential energy savings associated with this kind of a concept, a table such as this one will have to be filled out. What we have here is a variety of engines which were considered when we did this job in 1975. (Conventional spark ignition engines, stratified charge including the diesel, gas turbines, steam, stirling, and even battery electric.) Across the top, we have listed all the potential resources. What you would like to do is figure out the energy efficiency of utilizing fuels from these resources in each of these engines and try to come up with an optimum system.

In making these evaluations, we have to remain cognizant of the fact that the entire system has to work within the environmental constraints that have been placed upon it and that the transportation system using the fuel has to continue to provide a useful, economic service to the consumer. With this background in hand, what are the R&D challenges that await us?

First and foremost, what we have touched on many times in these meetings is the challenge to the Department of Energy and to the energy companies to provide us with the fuels to evaluate. The biggest hang-up today in the whole effort has been a lack of coal- and shale-derived hydrocarbon fuels for laboratory engine and subsequent vehicle evaluation by the automotive industry. Not having these fuels has led to a situation where lots of attention has been focused on testing alcohols and hydrogen, not necessarily because of their tremendous energy benefits for the future, but primarily because they have been available. When the hydrocarbon fuels from coal and oil shale are available, they can be used to investigate a variety of factors, including, first, their basic combustion systems. This can be done in laboratory studies where we can do the basic research to provide understanding, which then can be carried over to engine studies.

We should look at the effects of fuel composition, specifically the hydrogen-to-carbon ratio, the aromatic content, and the aromatic composition and their effects on particulate and polynuclear aromatic hydrocarbon emissions. We should look at the effects of impurities such as sulfur, oxygen, nitrogen, and ash and their effects on emissions, fuel stability, and engine durability. In all likelihood, an iterative approach will be involved to come up with the most efficient fuel-engine combinations. Thus, this will require a close interaction between the fuel supplier and the fuel user.

The Department of Energy should encourage and become involved with this type of activity. The potential payoff regarding conservation of U.S. energy resources may be high or it may not exist; however, we will never know unless we give this system a try.

This leads me back to some prior comments where I indicated that GM had responded to a DOE Program Opportunity Notice regarding a coal liquids refinery. Our response was part of a team effort which was headed by the Gulf Research and Development Company. The objective of the PON which was initially issued in September 1976 was

to define, construct, and operate a refining facility to produce marketable quality gasoline and furnace oil from coal-derived synthetic crude oil. GM, as part of this effort, proposed inclusion of less-refined fuels as part of our portion of the program regarding evaluation of automotive-type fuels. We had an extremely difficult time even convincing the Department of Energy to let us include this as part of our proposal. After many months of negotiations and considerable efforts on the behalf of the team members, our 5-inch-thick proposal was delivered to DOE on July 1, 1977. DOE was to announce award of this proposal for this contract in early 1978. Today, no response has been received, although the grapevine has indicated that no contract will be awarded. I think this leads to what I consider to be a significant failing on the part of the Department of Energy. All the team members on our team (I am sure the same situation exists with the other respondents to the PON) are somewhat disenchanted with the Department of Energy. Since I am proposing that DOE be an intimate partner in any future evaluations, I think the people, especially in the Fossil Energy Branch, in the Department of Energy have some fence mending to do. I think also that if we have any future meetings of this type, that those people who control the programs that will generate the fuels should be in attendance. I am somewhat disappointed that we weren't successful in having them at this meeting, because I think hearing this kind of message directly and not secondhand would be much more effective.

R.E. Baker (Ford):

One of the primary objectives of this conference, it seems to me, is to define what the finished properties of synfuels ought to be. How finished should they be? How far should they go? Is there any need to do something different from what we have today? In order to answer those kinds of questions, it is necessary to know where the fuels are going to be used, how they are going to replace the petroleum fuels that are in use now. In order to properly do this, all the users of petroleum products have got to be considered jointly. I guess what I am saying is the system study that we have referred to is the starting point.

That brings me around to my concern that there doesn't seem to be a way for a refiner to generally face up to his government organization. DOE does not seem to be able to consider all possible uses, all various types of users jointly, and I believe this is the problem that Gene Ecklund himself has brought to our attention as well as anyone. That is an impasse that we have to recognize, we have to face up to and somehow deal with. I am not sure that I have the solution, but it is certainly a great concern because of the importance of the Department of Energy participation in any of these projects.

What fuel should we develop? Should we concentrate on shale? Should we concentrate on coal? Tar sands? Whatever. I would like to echo a comment that was made by Commander Lukens a couple of days ago and that is that we don't really have to make a decision either/or. There are very good reasons why synthetic fuels can be complementary. Clearly, we have needs for distillates. We have needs for highly paraffinic-type materials. There are also very real advantages to making fuels that are highly aromatic. And there is every reason to believe that when we take a look at the whole system, at all of the uses, there are places for a variety of synfuels. That is going to be necessary so we can decide how much effort to put on shale and how much effort to put on coal, and so on.

Let me say a few words about the transportation industry that I am involved in. It seems to me that we have the same concern, we want to determine whether or not we do need a new engine. In order to determine whether we ought to build a new engine to utilize synthetic fuels, we have to know whether or not there are any advantages to making a fuel that is different from the fuels we have today. I am saying the same thing you have already heard several times. If we can decide now that there is no advantage to building a new engine, then the R&D work as far as we are concerned is done. All the R&D work that has to be done is strictly process, we go out there and make the fuels and we won't worry about new engines because after all we are showing that the engines we have are pretty good engines. The diesel engine is a very efficient engine. Some of the engines that will be coming along are very efficient engines, and we will be achieving higher efficiency without basically new power plants. So the question is (there may be other reasons, there may be

emissions impact and so on that we will have to deal with later) should we have a new engine for new fuels? In order to know that, we have to know how much energy is saved overall when we make these engines. It is necessary to do tradeoff studies, to determine how much energy is saved at the refinery as compared with how much energy is lost in compromises in the engine to accept those fuels. DOE does have an important role to play in that process. It will happen, I am sure, without DOE's support, maybe it will happen in spite of DOE's activities. I am not sure, but it can happen a lot sooner, it can be coordinated a lot better, and we don't have to rely upon evolution with a little bit of policy making at the beginning.

Let me now stand up and wave a red flag a little bit more strongly than perhaps it has been waved so far, the environmental impact flag. I really think that we ought to face up to the fact that we don't know how big are the problems of environmental impact (and they are potentially very large problems). As far as I am concerned, they could stop many of the things that we are considering doing. It doesn't mean that we don't do them, it means that we have to understand what they really mean. We have to do something very effective about that. They have to be included in economics for example. If you are talking about shale are you really going to be able to dispose of all of the waste products from shale from refining rock and all of the rest in an environmentally acceptable way? I guess perhaps the automotive industry is sensitive about this issue. Right now, we are in the throes of trying to define what "health effect impacts" really means. EPA has told us to jump on this issue and now (while we are all in the air) they have not yet said how high we should jump. There is a very real concern that highly aromatic fuels that might be produced in the future would not be acceptable from the standpoint of PNA concentration. What are the health effects from exhaust emission? The list goes on and on. We need a tremendous amount of help in research on what those effects are, how important they are, what tests are necessary to define what is and is not important. The whole area is wide open. That sounds a little bit negative, but what I am trying to say is that research needs are very large in that area. I guess those are my major concerns.

R.K. Pefley (Univ. Santa Clara):

I would like to make some general observations about the sessions here. Maybe you will agree or disagree, but hopefully it will provide some more food for thought.

Number one, I was struck by how far ahead the military is in the development of alternate fuels as compared with civilian agencies. That is good in terms of domestic self-preservation. I did think the cooperation between the agencies that appeared here is excellent and should be pursued intensely. However, there is some concern because they have made advanced progress that the civilian agencies might blindly follow simply because of shortened lead times. So, hopefully the cooperation will really take place, our tax dollar almost demands it. But also hopefully the civilian agencies will insist on a broad insight in investigations as this alternate energy issue evolves.

I was also somewhat thunderstruck to hear the FAA talking about doubling the jet fuel supplies in the next ten years to satisfy demand with no discussion of alternate plans. I am just puzzled how this country (now using one third of the world's energy supplies) can go ahead and program that way without considering the rest of the world. To me, the best way to deal with the rest of the world is to lead the way in developing alternate fuels, which we are not doing. If we go another 10 years and continue to consume a supply at the rate we are now projecting, I think we will earn the contempt of the rest of the world.

I was puzzled some about the absence of discussion of synfuels from pyrolytic oils associated with biomass. I don't quite know the definition of the conference here, but it seemed that the pyrolytic oils might fit into the discussion that has gone on here. I have not heard any mention of that in the alcohol symposia, and now I don't hear any here. It seems to me that it is a missing element.

I really have two objectives in presenting these slides (not included in proceedings). Obviously, one objective is to get alcohol on stage. The other objective is to extend the issue that Dick Baker and Andy Parker talked about in terms of a systems approach. What you are looking at is a vehicle that in 7 years has never had anything but

alcohol in it. It has about $100.00 worth of modifications. It has been stopped and started 10 times a day and still has the original engine fuel system, etc., and it is driven by the meter readers of the City of Santa Clara. It is just being retired, and we are going to take a look at it in detail.

The point is—at this time, we can say what does it cost us to run our car. Those are basic questions. I was fascinated in the response from you all, you put number one priority as domestic supply. Health and safety was second, and cost of operating the car in terms of fuel cost was third. So, in effect, you have put an assessment (and I really think we need to broaden out) on these economic questions.

We have made a lot of progress in technology by taking a very narrow question and dealing with it efficiently. But the public is dissatisfied with that. Now in this alternate fuels issue, you have a chance to look at a broader picture. We need to ask more questions of what is this worth.

Here you look at the emissions in a photochemical smog chamber using a hydrocarbon that is typically found in gasoline and methanol. The NO_2 and the ozone production and the upper two curves go with that emission from the automobile's using a key product in the gasoline sense. The lower two curves of NO_2 and ozone go with the photochemical reactivity in the smog chamber when the emission is primarily methanol. When you look at the photochemical reactivity of methanol, you find it down with methane and ethane. In effect, the reactivity is essentially extremely low. As you see, we never get to an ozone peak even after eight hours. So, one can say, what is it worth to reduce photochemical smog? I thought that Mr. Wheeler made a very important point: What is it worth to get rid of the mutagens and carcinogens in our atmosphere? We need to get these questions answered in a hard economic sense. I don't quite know how to do this, but it should be a serious portion of our activities.

What you are looking at here (and some of you have seen this before) is an octopus that is drunk on methanol. When you consider marine spills with alcohol, the scenario is entirely different from gasoline or crude oil spills. First, there is absolutely no fire hazard. But, secondly, it goes into solution in the sea water and so you get an entirely different reaction. We have studies going on, and what we find is that—where you all enjoyed ethanol last night—this guy prefers methanol. The invertebrate in the marine world likes methanols better than ethanol. This guy gets gray and sick if you give him ethanol. But if you give him methanol, he turns red and becomes combative. He really wants to take you on. The essence of the story is that the work we have done to date indicates that methanol is part of the ecosystem. We find in the estuary and in pools of the ocean that there is actually marine life that produces methanol. The general impression is that it would not produce a long-term disaster if there were a major marine spill. Dr. Delessque of our biology department is giving a talk in Detroit at the contractors' meeting next week on this subject. Again, I am just using this as a carrier to say: what is it worth to have a cleaner environment if we have a major spill; what is it worth to have less of an ecological disaster.

I would like to leave you with those statements because I do think that this system's approach to the economic evaluation of alternate fuels is very important, but should include the environment, health and safety, and domestic supply. I don't think we know how to do that very well. I have talked to some of the economics people on our campus, and it really demands new economics. I think this group can create pressure on the economics departments of corporations, economic students, and the government to address these issues and come up with a legitimate means which will allow us to make fair assessmenst as we move into alternate fuels. Thank you, that is all I have to say.

R.D. Fleming (DOE-TEC):

That concludes our prepared discussions of the panel.

I would like to say one thing that I was pleased to hear that some of the automotive people were indicating more R&D needs to be done with respect to optimizing the total system going from resource to fuel processing to refining to end use (which just happened to be on the top of my list).

As you recall, new hydrocarbons are at the top of the list in priority indicating that we would like to see more R&D done in this area to optimize energy utilization when considering all of the factors from resource to end use.

Gene Ecklund (DOE-TEC):

There is one point that I think might be pertinent which Roy Quillian mentioned in some of his questions late yesterday to the university people: I think we need to identify our educational needs as far as this whole area is concerned; educational needs in the universities but also in reeducation of people like ourselves and our compatriots. We have an enormous capability built up over several generations on how to utilize petroleum. We have lots of sophisticated techniques and of course the things that are being taught to the students today in the universities are things that have evolved over a period of time, many of them in the last decade or so. It would seem logical that we are going to need these same kinds of things when we move into synfuels. I don't think any of us at this stage of the game can define what they are. I know that the coming years will see evolutionary changes. These, I believe (and Roy Quillian is a champion of this), will take the form of new analytical and projective tools for science and technology. We have heard a comment on how the people in the refinery business might look at putting syncrudes into refineries. Wouldn't it be great if we could accurately anticipate just how to handle these materials. That is just kind of scratching the surface, we need it all of the way across the board. Education is the key.

OPEN DISCUSSION

Speaker 1:

I want to talk about the matter of source of material again. There has been a lot of concern here about getting sufficient material to work with so that you can conduct the tests and development that you want. It is really worth while to review the events going on now and what you can learn from them.

As you know, Congress has approved going ahead on both SRC-I (which provides a solid product to be burned in utilities) and SRC-II (which gives the heavy material designed for utilities and in which there is not a great deal of interest for refining). Of course, the idea was to displace oil from utilities.

Then, you may have read that H-Coal has very recently made a proposal to the government to go ahead with that process in a demonstration plant. I understand that Exxon has not made their proposal on Exxon Donor Solvent that would go into a large-scale demonstration plant. In addition, of course, you have alcohol about which there has been a great deal of discussion. There is a great deal known about shale, and it supposedly could be moved in a few years.

Now if you suddenly got a large amount of any one of these I don't know that you would be home free because the argument and the discussion in this country would go on interminably about whether that is the way to go. It doesn't look like any one of these has the capacity to really give you what you are looking for by the year 2000. Certainly, alcohol could move more rapidly now but that is really a political and economic question. Shale could move fairly quickly, but again that is primarily an environmental question and an economic question all tied up with subsidy and so forth.

But if any one of these moves, aren't we back where we were, because you can't really count on any one of these providing the fuels to solve all the problems?

I call your attention to the decades of work that the petroleum industry did in building up the current petroleum industry. There really aren't very many veterans of this era actually still employed in the petroleum industry, because so many of them have retired. But through those years, there was an enormous amount of work of a basic nature wherein they really developed the petroleum industry by studying what happens to pure compounds and understanding all about their molecular species. These studies went into such depth as: what types of molecules give superior knock properties, combustion properties? What types of molecules give superior lubricating properties, etc.?

I really suspect that a great deal of basic work will eventually be done in the next two decades, and I think we probably will come to the conclusion that a great deal more research should be done on pure compounds and get to know how to cope with these different materials because if you know how to cope, you already know pretty well what kinds of materials you are going to encounter from any of these sources. If you learn how to cope with them, you can deal with any fuels.

Now to get back to the point, suppose you had a large source of any one of these fuels. I doubt if you would be home free because you wouldn't really be sure that that was going to be the solution. I detect here a large tone of effort to test things. I just wanted to bring to your attention that perhaps the greatest emphasis for some time now needs to be put on a more basic level of understanding. Why these things behave like they do because with that understanding, the parts of the business you gentlemen represent are going to be able to contend with a variety of different things, whether it is shaded heavily towards alcohol or toward shale, etc. Along that line, I am even told that shale oil from different sources, whether it is retorted or modified in situ (or indeed from different parts of strata), has significant compositional differences. These differences are of the nature that you really need this more basic extensive information to cope with them satisfactorily versus a purely empirical program.

Speaker 2:

I would like to point out a few things that were mentioned about engines. We haven't really said quite enough about engines. I think there has been a slight air of over optimism about what we are going to do in the future about engines. Some

people think that they can produce some weird fuel and inevitably an engine will be produced that will consume it. This is, perhaps, over optimistic.

If we look at the whole scene of the engine industry, we can see that the heavy diesel engine has been there for a very long time. I see nothing on the horizon to touch it. The only changes I see in the heavy diesel situation are some tightening up in fuel specifications and here I would echo Dick Baker from Ford. The American public is not going to tolerate deterioration of the environment. Once you have had decent air and you have gotten used to that, it is going to be easy to sell you the idea that it should be maintained, at least, if not improved. So I think that possibly in the heavy diesel on the heavy trucking side, we might see improved fuels rather than what the oil industries say inevitably is that the fuels will get worse and worse. I think legislation may force some slight changes in specifications to lower the toxicity of the sorts which an engine running by diffusion burning is inevitably going to produce.

Now, stratified charge engines made a big splurge some years ago, and they are still being worked on quite hard behind the scene. The breakthrough doesn't appear yet. If they are going to run on heavier fuels with in-cylinder injection, inevitably they are going to partake of this problem to fusion burning particulates and toxics frozen out on the particulate. This, I believe, will hardly be tolerable. We are working hard to try to develop cleanup systems for these materials. We are having some slight success at this moment. That is a problem which faces the stratified charge engine, if we are going to treat it as an engine which could consume almost any specification of fuel.

Now Ford is apparently more limited in their objectives. They are looking towards the stratified charge engine as being an engine which is not octane-dominated. That is fine, and we all look forward to the results of this. This could be an excellent engine to compete with the diesel in the larger passenger car sizes.

General Motors has done an excellent job with the dieselized Olds. Everybody is amazed that a diesel engine could be so civilized. In fact, it even amazed Ricardo that it was so civilized. It even amazed me, and I am a skeptic. It has many advantages, but, of course, again it is confronting the environmental problem of toxic particulates. Now some people say, what is all this particulate business? Why has it suddenly arisen? It has suddenly arisen due to this world-wide interest in the fact that, in the environment, there are a number of unfavorable bodies which build up and are additive in their impact. Every system or every type of chemical or whatever, all of these materials probably have an additive effect. So, every system has to take its share of the blame for possible upsurges in diseases like cancer, various other degenerative diseases and, in the problems of genetic defects (which is a thing we should all be very worried about), carrying on down through the generations.

The environment is going to be looked at very, very hard in these respects, there is no doubt about it. So, the stratified charge engines and the diesels may well battle it out for the 4000- to 4500-pound car. But despite the brave efforts of, for instance, Volkswagen and the small Rabbit (which is a brilliant car), one doesn't really see every small car being a diesel car. They are inevitably going to be more expensive, more difficult to produce. The smaller you go, the tolerances get more and more critical. The clearance between the top of the piston and the head gets very, very critical and crucial. One has to go to almost selective production methods, and these are going to be more expensive than for the gasoline engine. So I am suggesting that one thing in the States that is inevitable (and I think desirable) is many more small cars around 1000 cc's which would have adequate holding capacities for limited shopping and a fellow going to work. And, of course, in the American scene, you will have the big car at home anyway waiting to do those special jobs. But I see a very large unsurge in small vehicles. These, I am sure, are going to be high-compression gasoline engines. I would suggest that it would be extremely helpful if EPA and the other agencies could raise the limits on extremely severe emission standards to encourage these small cars. Now they would run on high-octane gasoline. In Europe, we can run these cars at compression ratios of 16 to 1 now with a modern ignition system. If one was running on, say, a highly aromatic fuel, then the platimum catalyst would almost certainly take care of the exhaust. These engines can be run lean to improve the loss of fuel economy by throttling. You can get quite an improvement in range

unthrottled by leaning, and this is good for efficiency. We are on the verge of equalizing the small swirl chamber diesel engine fuel consumptions with these motors. Certainly they are going to be cheaper. So this could be a good scenario for the future. But, I think it would to some extent depend on some encouragement. I am not suggesting that the ambient air quality be deteriorated, particularly with these. It is really a question of the NO_x legislation. I think the rest could be fairly easily taken care of. So, I think we really have to look very hard at the NO_x legislation because that is where we have a confrontation. However, Dick Pefley would immediately say "Well, we have your fuel—methanol or ethanol." That is quite true. That could be, but of course there is clearly at the moment an economic barrier to that. Also, with a small car, it would not be too desirable to double the size of the fuel tank, although that is a vehicle design problem. I would certainly bow to the vehicles' designs. I am sure they could do this.

That is just really how I, personally, see the sort of thing that could happen in the future. Now I don't see any slot in this for a very heavily deteriorated fuel specification. So, I am fully in agreement that we should keep the best for transportation. Let us keep it good. Let us research it and let us research its effect on the environment heavily. This is absolutely vital worldwide. Let us keep anything that is of poor characteristics or poor specifications where it can be taken care of in heavy plant and public utilities.

Speaker 3:

A problem which has kind of been an undercurrent here, and probably at all conferences like this, has finally raised its ugly head this morning and that is the fact that the oil companies or petroleum refiners have an enormous investment in refining petroleum. They have millions of dollars of capital investments out there which are good for refining petroleum. However, we also know that most of these plants are relatively small and some of them are old and in various stages of age in fact. There is always a replacement market for refining plants.

Then the other observation that was brought up this morning is the fact the Arabians and the other oil producers are going to get into the refining game. They are going to build the biggest, most efficient plants that they can build, which means that, in 10 or 15 years, you are going to have a situation where these people are not only producing their own white naphthas and middle distillates that they are going to sell all over the world, but they are going to be producing it better than you can do. It is just like what the steel industry in Japan is doing to our steel industry now. So, the challenge that you have is: when you get the bottoms that these people are going to sell you, plus the bad oil that we are going to get from our own wells, plus the dirty shale and the dirty coal that you are telling us we are going to get, instead of building new refineries to replace the old ones which are getting worn out, you are going to have to build refineries that can handle the bad stuff rather than the good stuff. That is, I think, a basic challenge that the oil people are going to have to face in the next 15 years or you are not going to get the job done.

Speaker 4:

I suppose I feel compelled to respond to that, being from the petroleum industry. Yes, we agree. You have to build refineries and modify refineries continually to accept dirtier, heavier feed stocks. It has been going on since the institution of the refining industry and is still going on. Nobody is ahead of us; we will be there.

Speaker 5:

I have a couple of slides (not included in proceedings) here on the H-COAL process that the audience might be interested in.

Here is an H-COAL plant that is going to start up in Cattletsville, Kentucky with a 600 ton per day start up scheduled for 1979. You have the H-OIL processes that have been going on (Lake Charles, Louisiana—6000 barrels per day operation already in 15 years). There is one in Kuwait (56,000 barrels per day, 10 years in operation). There is one in Mexico (5 years in operation).

If you were to put in tar sand bitumen, solid-free, the products that you get out are shown on the first line. To 430°F you get 22 percent, 430 to 975°F you get 61 percent, and 975°F plus is 5.8 percent. If you put in 100 pounds, you get 86 pounds of synthetic crude out. On a volume basis,

you get 101.2 percent out. If you go with an API of 8.8° which is pretty heavy, your product comes out as around 33 percent, I think.

The investment per barrel per day installed is $1,100. So, if you are talking about one million barrels per day, that is a lot of money. The fuel required is 70,000 Btu's. Power required is given. There is 6 kilowatts. Steam required is 19 pounds. Cooling duty is 260,000 Btu. Water process is 5.1 gallons. Catalyst is $.16 per barrel. Hydrogen consumption for that particular fuel was 1400 cubic feet. The pressure of the hydrogen going in must be 700 psi gage.

Speaker 6:

I would like to also take this opportunity to thank the organizers of this conference. I don't think we need to apologize for anything or for repeating ideas and things of that sort. I think there is a lot of good that has come out of this conference. We will be all able to go back and mull things over and formulate our ideas and to the people of DOE and SwRI, thank you very much for the conference.

I would like to say one other thing here. In my opening remarks yesterday at our session, I alluded to some work that we were doing on pure compounds at our institute and it was alluded to again today. I think that it is important that we go back to the basics and look again. I can remember just 20 years ago, we started working with alcohol in fumigation at Penn State. We coined that word, as a matter of fact, at Penn State. Our emphasis at that time was to come up with a smoke deterrent for a diesel engine. I think that if we had only had some of the research tools 20 years ago that we now have, how much more we could have learned from that earlier project. Today, we do have some very sophisticated means to look at our results and to help us in our studies. I also mentioned some other work that we are now doing with pure compounds, things that one would rather think that were done or might have been done a long time ago. We could find nothing in the open literature. One thing that we are doing and have been doing for quite some time is trying to come up with screening techniques using pure compounds to predict how future fuels might react in known hardware of today because we don't have any future hardware around. So, we are doing this in conventional diesel and SI engines, using CFR-type apparatus. We are beginning to get some insight into how the combustion characteristics in simple constant volume bomb tests do influence the behavior of these pure compounds when you run them in the engine. For example, knock is one thing that we have taken a real hard long look at, and correlations are beginning to surface.

Now, one other area that I think is extremely important because many people are concerned with the environment and how the particular "bad guys" are born in the engine. We have decided to go back with our constant volume bomb and look at surface phenomena again in automotive diesels, and we all know the reasons why. That is, all of the current light-duty automotive diesels are pre-cup engines with glow-plugs. How do pre-combustion chambers and glow-plugs influence the formation of particulates in an engine? We are doing these studies with pure compounds.

When we got back to this work, we tried to build our base line study around the primary reference fuels. One of them we wanted to use was cetane. If anyone has tried to buy cetane lately, you will find it is about as valuable in price as the synfuels you are talking about. I just couldn't believe it when I found that I had to pay about $300.00 per gallon for cetane. Now maybe there are some people here that know something that I don't, but I would still like to be able to work with some cetane.