RESEARCH ON GROUND PROPULSION SYSTEMS

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

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ON

H.R. 10392

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Mr. CARTER, JR. I have a prepared statement here concerning our comments on the bill. I also have a prepared statement on our Carter Steam Car which I'll be glad to read and I have a short movie showing our car. It is about 5 minutes long.

Mr. SYMINGTON. You can present your testimony any way you like.

Mr. CARTER, JR. In the interest of saving time, I will read the comments to your bill and if you have any questions at that time, we will stop and answer them or go into the statement on the Carter steam car.

[A biographical sketch of Mr. Carter, Jr., and Mr. Carter, Sr., follows:]

JAY W. CARTER, JR.

Education

BSME, Texas Technological College, 1968.

Experience

Bell Helicopter Company, 1968–1970. Joined Bell as a Research and Development Engineer. Worked as designer on Model 300 proprotor blade and on the D 212 thin tip extended chord blade. Principal designer of D 270 proprotor blade and folding mechanism. Design engineer on D 272 folding proprotor blade.

Jay Carter Enterprises, 1970 to present. Worked on design and development of Rankin Cycle system which was installed in a Volkswagen squareback.

Professional societies

American Helicopter Society, American Society of Mechanical Engineers, Texas Society of Professional Engineers.

Sampling of papers and publications

(1) A Student's Designed and Built Gyrocopter, presented to ASME Southwest Regional Conference, Spring 1967.

(2) How to Design Your Own Airplane, presented to the Experimental Aircraft Association, Dallas Chapter, March through November, 1969.

Miscellaneous

Manager of Texas Tech Science and Engineering Show 1965–1966, Vice-President Texas Tech Student Association 1967–1968. Co-inventor on patent application for advance technology proprotor blade at Bell Helicopter. Designed and built two gyrocopters while going to school. Started building an all fiberglass pusher airplane while at Bell Helicopter. Vice-President Experimental Aircraft Association, Dallas Chapter and Wichita Falls Chapter. Private pilot's license, single engine land.

J. WAYNE CARTER, SR.

Born June 26, 1923. Married, four children.

Education

High School, Ponca City, Okla., 1942.

Aircraft Engine School, Duncan Field, Tex.

Army Specialized Training Program, Engineering—Western Maryland College, Westminster, Md., 1943–1944.

BSME, Texas Tech University, 1946–1949.

Experience

Roustabout in oil fields, summers 1939, 1940, 1941.

Part time machine shop work, 1946, 1947, 1948.

Texas Power & Light Co., Trinidad, Tex., Plant, February 1949–October 1952, assistant mechanical engineer.

Industrial Generating Co., Rockdale, Tex., October 1952–September 1955. Chief mechanical engineer in charge of all mechanical maintenance at the 360,000 Lignite burning power plant.

Fish Engineering Co., Houston, Tex., October 1955–February 1957. Design and development engineer on calcium chloride dehydration units being developed for gas wells.

Black, Sivalls & Bryson, Inc., Oklahoma City, Okla., March 1957 to August 1960. Project engineer at the research lab. Designed special machines for winding large diameter fiberglass tanks. These machines were used to wind the first successful Polaris and Minuteman missiles made with glass fibers.

Black, Sivalls & Bryson, Inc., filament structures division, Ardmore, Okla., March 1957–October 1963. Chief engineer. This division was formed and a large manufacturing plant built as a result of the success at the research lab in Oklahoma City. All sizes of filament wound fiberglass tanks were made at this facility as well as several hundred Minuteman and Polaris missile chambers.

Wichita Falls Research Co., Wichita Falls, Tex., October 1963–April 1964. Resigned from BS & B to form Wichita Falls Research Co. Started design and development work on a machine to continuously produce filament wound fiberglass pipe.

Texas Reinforced Plastics, Inc., Burkburnett, Tex., May 1964 to present. President and major stockholder. Sold pipe manufacturing equipment and patent application to CIBA Products Co. in February 1965. T.R.P. has continued to develop new products, and design and build special machinery for the CIBA pipe operation.

Jay Carter Enterprises, Inc. Formed in 1969 to develop new ideas and to do contract work for Jay Carter Associates. President.

Patents

Approximately 10 patents have been issued in my name, with several in foreign countries. Several more patent applications have been filed in the patent office.

Miscellaneous

Member, American Society of Mechanical Engineers code committee for plastic pressure vessels.

Member, Experimental Aircraft Association.

Member, Popular Rotorcraft Association.

Member, Steam Automobile Club of America.

STATEMENT OF JAY CARTER, JR., JAY CARTER ENTERPRISES, BURKBURNETT, TEX., ACCOMPANIED BY J. W. CARTER, SR., PRESIDENT, TEXAS REINFORCED PLASTICS, INC.

Mr. CARTER, JR. We, at Jay Carter Enterprises, are honored to be invited to appear here today, and appreciate the opportunity to discuss our views on H.R. 10392. Accompanying me today is my father, J. W. Carter, Sr., who is president of Texas Reinforced Plastics, Inc., a research and development company. Six years ago he started Jay Carter Enterprises with the goal of developing a steam powered automobile that would be competitive with the internal combustion engine.

We support bill H.R. 10392 and approve of the use of NASA for ground propulsion systems research and development, because we feel there is a need for the development of an efficient, clean-burning propulsion system with multifuel capabilities. However, NASA's program should remain separate and independent of any other agencies formed or that may be formed for this type work. We believe that competition and the incentives it develops are just as important in government as it is in industry.

There are two main items which must be incorporated into the project to insure that the best solutions are obtained in the quickest and most efficient manner.

First, it is necessary that competition and the incentives it develops are generated between two or more government agencies striving toward a common cause. There may be overlapping efforts between the agencies, but because of the competition and the desire between the agencies to get credit for having the first and best solution, the overall time and costs will be less. Certainly we want, as quickly as possible, to have an energy efficient, low polluting, multifuel power system, but at the same time we don't want to rush into something that we are going to have to live with for the next half century. Competition between government agencies will help assure that this won't happen.

Additional incentives must be given to those corporations awarded the contract. A cost-plus contract is not conducive to efficient, creative performance. If the Government expects to get qualified companies to bid on their contracts or to get really aggressive, creative work out of their contractors, then the contractors should be permitted to retain at least half of any profits, royalties, or patents which are obtained as a result of their efforts.

I understand that NASA's primary effort will be in the area of management, analysis, tests, and evaluation and that the bulk of the work is accomplished outside the Government, in the private sector, where it belongs. Therefore, they will be inviting requests for proposals from industry. I strongly suggest that they do not limit proposals to large companies. There is also creative ability in small firms.

As I mentioned earlier, we have been working on a steam system for an automobile. We recently had our steam-powered Volkswagen tested by the EPA lab in Ann Arbor, where our car became first of any type to meet the original 1976 emission levels without any add-on control devices.

We will be glad to answer any questions about our steam car, the EPA test results, or any comment we have made about H.R. 10392. If there are no questions we can go on to describe our system, and what we have done.

Mr. SYMINGTON. I think we can go ahead unless Mr. Brown has a question here.

Mr. BROWN. I think we ought to go ahead.

Mr. CARTER, JR. We recently completed tests on our steam-powered Volkswagen at the Environmental Protection Agency lab in Ann Arbor, Mich., where our car became the first of any type to meet the very strict original 1976 emission levels without any add-on emission control devices.

Besides getting extremely low emission, our fuel economy was 24.7 mpg at 30 mph, 20.9 mpg at 50 mph, 14.9 mpg over a cold start 1975 driving cycle, and 17.3 mpg over the Federal highway driving cycle.

While these fuel economy numbers are fair, they do indicate the potential for very good fuel economy, equal to or better than 1974 automobile fuel economies, based on the tested baseline data and the known relative easy areas for improvements. Based on the results of our first steam car, our second car will have emissions at least one-third of the original 1976 emission levels, over 25 mpg at 55 mph, over 20 mpg over the Federal driving cycle, and a drive-away time from a cold start of 15 seconds or less.

Initially, research was renewed on the steam engine because of its inherent low emissions, but besides having very low emission and excellent fuel economy, there are several other factors which make the steam engine an excellent alternative to the internal combustion engine.

The steam system can use a variety of different fuels. It is not limited to burning only petroleum products, as a matter of fact, it can burn coal tar, a derivative of coal. There is reported to be enough coal in the United States to supply our energy needs for 800 years. So the sooner we change to burning coal products in our cars, and saving our petroleum products for other needs, the better off we are.

Also, the steam engine has the potential for extremely long life, on the order of at least 500,000 miles before overhauls. The application for taxis, buses, and trucks is ideally suited.

We have taken a fresh and new approach to many of the problems associated with a steam-powered vehicle, which is obvious since our first complete system fits into the Volkswagen engine compartment with the exception of a small ram-air condenser located up front. The total system weighs only 120 pounds more than the original internal combustion engine, and includes the condenser weight which is made out of lead and brass. Little effort was made to conserve weight on the first prototype.

Our automobile powerplant is a completely closed system which means we do not have to add water. We use the same water over and over again. We also do not lose any oil, which means we can virtually bathe our piston rings in oil. It is because of the almost perfect lubrication in our system, that enables our engine to last so long.

The expander puts out over 90 shaft horsepower from 35 cubic inches at 2,000 psi steam pressure and 5,000 rpm. The steam temperature is constant at 1,000° F.

The car was first driven around Burkburnett on March 15, 1972, over 2 years ago and now has accumulated over 4,500 road miles.

Drive-away time from a cold start as tested by EPA over the 1975 Federal driving cycle was 28 seconds and 32 seconds.

My father and I are both mechanical engineering graduates of Texas Tech University. My father is president of Texas Reinforced Plastics, Inc., a research and development company that develops reinforced fiber glass pipe and products for the oil and chemical industries. He developed the first successful glass filament wound rocket motor chambers for the Polaris missiles.

As a result of our recent tests, the steam engine can no longer be ignored as a possible practical alternative to the polluting internal combustion engine. The steam engine may be given a second chance to supply the power needs of the world as it did in the early years of our industrial revolution.

[The following attachments of Mr. Jay Carter, Jr. are as follows:]

	Miles per hour	Gear	Miles per gallon	HC, 0.41	CO, 3.5	NO_x, 0.4	T_1 [1]	T_2 [2]	T_A [3]	T_3 [4]	T_6 [5]	P_E
1st set of steady State data	10	1	10.5	0.48	3.37	0.53						
	10	2	13.7	.57	2.49	.30						
	20	2	17.1	.2	1.42	.29						
	20	3	20.9	.27	1.61	.22						
	30	3	21.8	.08	.68	.25						
	30	4	23.4	.11	.9	.22						
	40	4	22.8	.03	.44	.25						
	50	4	20.0	.01	.09	.28						
	60	4	17.4	.01	.07	.34						
1st highway driving cycle			16.3	.04	.47	.32						
1st Federal driving cycle			12.7	.34	1.33	.39						
2d set of steady State data	10	1	11.8	.31	2.56	.4						
	10	2	14.2	.48	2.59	.51						
	20	2	18.4	.05	.90	.29						
	20	3	21.8	.28	1.18	.24						
	30	3	23.8	.05	.41	.27						
	30	4	24.7	.09	.65	.22	550	740	645	830	150	550
	40	4	23.7	.02	.24	.25	760	930	845	975	150	675
	50	4	20.9	.01	.16	.28	820	950	885	980	150	775
	60	4	17.4	0	.11	.34	870	950	910	980	140	925
2d highway driving cycle			17.3	.02	.28	.31						
2d Federal driving cycle			14.9	.399	1.08	.33	(7)	(7)	(7)	(7)	(7)	(7)

1 T_1 equals temperature of steam line connecting bottom 2 cylinders.
2 T_2 equals temperature of steam line connecting top 2 cylinders.
3 T_A equals average temperature feeding to cylinders.
4 T_3 equals boiler exit steam temperature.
5 T_6 equals temperature of water entering boiler.
6 P_E equals pressure of steam at expander.
7 Large HC number due to poor ignition at wide open fuel flow.

NOTES

The 2d set of data was run exactly the same as the 1st set of data, yet in every case the fuel economy was better in the 2d set of data. This increase in fuel economy is believed to be as a result that the rings were seating in. At the beginning of the tests there were less than 400 mi on the new rings. The fuel economy may still increase more as more time is put on the rings. You might also note the low TA due to poor insulation and radial configuration and the efficiency to be gained here and by increasing T_6.

As a matter of convenience, many of our accessories are driven by 24 v electric motors, running on 12 v. The electric motors are only about 50 percent efficient and the alternator also is only about 50 percent efficient, therefore, by driving most of our accessories mechanically instead of electrically, we can reduce the excessory load which the engine sees by as much as 50 percent.

We do not need a condenser fan for steady State speeds up to 70 mi per hour yet, for convenience sake, our fan is driven all of the time. At 50 mi per hour the 14 inch diameter fan turns at 4,250 rpm, and is absorbing a significant amount of horsepower.

Mr. SYMINGTON. Thank you very much, Mr. Carter, for an interesting and informative statement.

Did you have a film of this car that you wanted to show us?

Mr. CARTER, JR. Yes, we do.

Mr. SYMINGTON. Why don't we look at that now.

[At this point a short film was shown.]

Mr. CARTER, JR. This film was taken almost 2 years ago in October 1972. It was just before publicly releasing the fact that we had been building a steam engine for an automobile.

We felt like it was better to get a system built, developed, and put in a car before telling people what we had.

There have been a lot of people who talked about what they were going to do. There have been a lot of false starts with a steam car and we just didn't want to be classified in that category.

So very few had heard about our system until October 1972, when we invited Mr. Tifman who was then Director of the California State Legislature Federal Office, to come out and see us.

These shots were taken on the day that he came out.

You can see we have added some extra louvers on the fender well for more air flow. We have a large condenser in the rear. We added a small ram-air condenser up front. We have no trouble condensing all of our steam on a 100-degree day at 70 mph. As a matter of fact around June of last year, we drove our car back from San Antonio in 100-degree weather without any appreciable loss of water.

These shots were taken on our drive to the airport to pick up Mr. Tipman.

At this time, our system was completely automatic and by that I mean, you turn the key on, 20 to 25 seconds later, The car is ready to drive off. It operates exactly the same as a regular Volkswagen. You shift gears. We use the standard Volkswagen four-speed transmission. We have taken a new approach on our engine system which has enabled us to do a lot of wonderful things which no one else has been able to do. We have a valve system which requires no lubrication. It operates at high temperatures and high pressures since it has no high pressure nor high temperature seals. We operate at 2,000 psi pressure and 5,000 rpm which is the reason we can develop 3½ horsepower per cubic inch. We operate at a constant expansion ratio at 11.3 to 1, which enables us to get the most amount of energy out of the steam before we exhaust it into our condensers.

Here are some shots from the air. My father was doing the flying. I am doing, I would say, around 75 miles per hour. I wanted some nice shots passing several trucks. The speed limit at that time was 70 miles an hour. I have another shot where we are driving about 80. I think this is where we are going 80. The trucks along the flat highways of Texas drive a good 70 miles an hour. But even at 80 miles an hour, we are not at full throttle.

This is our shop. It is an airplane hangar. When we built this car there were two people on the payroll, a machinist and myself. My father helped a lot as a consultant. We have since hired two other fellows, a draftman and another machinist.

This is the instrument panel, although most of the instruments are in the glove compartment. We do a lot of driving of our car on the highway and, of course, it is set up so we can run tests on it.

Here is a view of the engine compartment. The white that you see is the insulation on two of the four cylinders.

Here is a shot of the expander. It is a 4-cylinder radial, 35 cubic inches displacement. The water pump is an integral part of the engine. The total package of what you see there weighs only 114 pounds and includes the expander, feed water pump, oil pump, throttle valve, and insulation. Our million-Btu, capacity boiler weighs 125 pounds, and that includes the blower motor and all the automatic controls. As I said, our total system weighs only 120 pounds more than the I.C. engine. This being the first prototype, I was very conservative in all my stress analysis of the engine, and of course, we had to build everything. We had to build the crank shaft, pistons, connecting rods, and cylinders. We had to develop all of our automatic controls, our temperature sensing units, our oil-water separator, and we even did the work on our condensers.

The fact is, we have taken a new approach on nearly every item on the steam system.

Mr. SYMINGTON. Thank you for a very interesting film.

I am going to have to leave at this time. Mr. Brown, will you take over the chair? I certainly would like to see that car one of these days.

Mr. CARTER, JR. We considered bringing it up here, but its a long way to bring the car. We had it at EPA and took a lot of people for a ride there. If you are ever down in our area, we would be glad to take you for a ride in our car.

Mr. SYMINGTON. We appreciate your testimony very much.

Mr. CARTER, JR. Thank you.

Mr. BROWN. I certainly want to express the appreciation of all of the members of the committee, and our interest in the work that you have done, Mr. Carter. The first question that occurs to me, and I imagine will occur to a lot of people, is how is a small operation like your own able to be as successful as you have been in developing this prototype car when the major automobile companies seem to have despaired of success.

I am sure there are legitimate reasons why Ford, for example, has decided not to continue with a major emphasis on the steamcar, and other major companies are the same way. But I'd like to hear your reaction to that. Do you think small companies are intrinsically better than big companies?

Mr. CARTER, JR. No; I don't think that is necessarily true. I think a lot of our success is probably due to attitude. We are privately financed and have not had the money to afford to make many mistakes, so we have to be very careful with what we do, and of course, because we stand to gain everything that we develop, the incentive is there for us to work on it nearly every minute of our working day. I take the project home with me. I take it to bed with me.

It is very easy to spend a lot of money when you get started on the wrong approach. That happens sometimes in research and development. It is very unfortunate when they spend a lot of money on the wrong approach, and it is unfortunate that they have given up so soon.

We have been fortunate, I believe, in that we have taken a good approach, and it is one that enabled us to do these nice and wonderful things.

Mr. BROWN. I want you to do justice to the big car companies. They say there is an intrinsic limit to what can be done with the steamcar in terms of fuel economy and so forth, theoretical limits which do not in their opinion justify devoting a major emphasis to it.

Are they being shortsighted in this analysis?

Mr. CARTER, SR. You see, there are theoretical limits, if we believe all the theory. But the thing is that the people do not know. No one knows how close we can approach those theoretical limits. In other words, when we design a system, is it going to be 40 percent of that theoretical limit or 85 percent of that theoretical limit? There, I think, is where the problem is. We only know from past experience how close we can come to that theoretical upper limit. If we base our thoughts on technology developed back in the 1920's and 1930's, and don't use modern technology, and don't move with the times, and we build a steam engine like 40 years ago, then there is no way we can complete with the I.C. engine. We have taken a fresh, new approach to this thing. We have thrown away the book and started over from scratch, so to speak. We operate at high pressures and high temperatures, and

we have a system that we can go to 3,000 pounds of pressure if we need to.

Mr. BROWN. We have been told by others who are working in this field there are certain problems with materials that occur at the higher pressures and temperatures?

Mr. CARTER, JR. You see, we operate at relatively low temperatures, 1,000° requiring no special materials, while the Sterling engine is going to be operating at nearly 1,500°, and the gas turbine, to get its efficiency, is going to operate at 2,000°. We have potential for going up to 1,200° in our present design with no material changes, but we should be able to equal the efficiency of the I.C. engine without using temperatures of more than 1,000°.

Mr. BROWN. Just one additional question. With the thrust of this bill which would authorize NASA to provide assistance in solving some of these technology problems, do you see this as a role which would contribute to the faster development of an alternative engine?

Mr. CARTER, JR. Yes, sir, I sure do. If you consider what we have done in 4 years on a very shoestring basis, then it stands to reason that as more money is put into our approach, then very significant gains can be realized and certainly some money by the Government would be very helpful. We have not had very much encouragement from anybody, and certainly we would like to see some help. I think the motor companies have kinds of tunnel vision when it comes to the steam engine. They decided its no good based on technology of 20 or 30 years ago, and that there is no future in it, and it is very sad. It is very sad indeed.

Mr. BROWN. Do your plans call for going into competition with the Big Three in the future?

Mr. CARTER, JR. What we would like to do, of course, is to sell our patent and development work to some major motor company. That is, the place where automobiles will be produced for the next 50 years. We are presently working on a second system in the event we can't interest the motor companies with the first one. We feel it will be unquestionably superior to the I.C. engine and it will blow the lid off of this thing.

Mr. BROWN. Mr. Winn, did you have any questions?

Mr. WINN. Thank you.

I was wondering about the money involved, to set aside $30 million for 5 years, do you think that is enough to fund a research program like you have in mind or for the entire research to be done, is it too much to do?

Mr. CARTER, JR. Well, our efforts don't require a lot of money. Some other organizations, because they are larger and probably they are not as efficient, do require more money. It is hard for me to say exactly; $30 million does seem like a small amount considering the impact and the importance of what we are working on. The sooner we do something about it, the better off we are all going to be.

Mr. WINN. I don't know how many companies such as yours are working on this. We see feature stories, some are publicizing their findings, some are still working behind the scenes and keeping their patents and ideas very secret. The question comes up, I think, do we need still another agency in this field when we have got fractionation already in the effort by the Department of the Army, and EPA, and the Department of Transportation and still others?

Mr. CARTER, JR. Well, granted there are several agencies that are doing work but their scope is very narrow. They have taken one approach and I think some of them are very wrong. I don't feel like they are going to make it with their approach. The more agencies that you can have, the better chance you will have of not running down a blind alley.

I like competition. I think it generates a lot of incentives, if it were managed right, and I think competition between Government agencies would be just as helpful and provide the same incentives as competition in industry.

Mr. WINN. I don't think there is any doubt that competition is good, and most of us on this committee feel competition is healthy. At the same time, the energy crisis was simply a good example of where we had so many agencies and committees, 17 out of our 28 committees were involved in some parts of trying to solve the energy crisis. It seems to me like we are going off in all directions. I wonder if we might be doing the same thing?

Mr. CARTER, JR. I agree that theoretically it does sound good to have all these agencies brought together under one heading, and maybe it will work. But when you have only one central group, the group is only going to be as good as the people that are put in charge. And if these people are more interested in their own political gains, their own agencies or building up their own bureaucracy, or what not, it stands to be a disaster that we cannot afford. There needs to be some checks and balances and I think competition is a good check and balance for this type of, you know, situation that could occur.

Mr. WINN. You may have covered this, do you have any other cars or do you just have the one prototype?

Mr. CARTER, JR. Well, unfortunately, we could just afford one prototype. For our next generation of cars, we are going to build at least two systems and have another system that will be on the test stand all the time. In the past whenever we had a problem and wanted to do some work, our whole system was shut down. And it hurt us, but, of course, we had no other choice. We asked for help, but, we are not a very large company and a lot of people say, "what makes you think you can do it when large companies can't do it."

Mr. WINN. What is your answer?

Mr. CARTER, JR. What is my answer?

Mr. WINN. If people ask you that, what is your answer?

Mr. CARTER, JR. It is really hard to dispute. About all we can say is; we have taken a different approach, just look at what we got. Unfortunately, it took us almost a year of concentrated effort before we could get EPA to test our car. It is doubtful as to whether they would have ever tested our car if it hadn't been for the help of some of our Congressmen. That has been the situation.

Mr. WINN. It may be they have their heads in the sand and won't take it out.

Mr. CARTER, JR. They have their own program and, I understand, they probably have a lot of people coming to them who say they have a solution and so after a while they don't pay attention to anyone.

Mr. WINN. What you gentlemen have said is pretty discouraging to those of us who are trying to accomplish something in this field, and if we are closing our eyes or ignoring the possibilities, many people have said that it may well be a small mechanic somewhere working out of a small garage or in the back of a plant or something that would come up with the final answer to this.

Mr. CARTER, JR. There are a lot of small companies across the country that are working on similar projects. I think they probably have had the same negative response that we have had.

Mr. CARTER, SR. As you probably know, there are a lot of very smart people in these big companies. In fact, there are smart people all over the world. Even though you have a big company, there are probably only one or two men in that big company that are calling the shots. This is where the trouble comes in. A lot of their engineers know the boss is making a mistake. They are not in a position to call the shots. Just because it is a big company doesn't mean they are going to be the one with the answer. I have been in competition with big companies all my life and big companies don't scare me as far as competition. Their money scares me.

Mr. CARTER, JR. They do have the technical potential, but it is difficult for them to utilize it to the fullest extent.

Mr. WINN. Thank you very much.

Mr. HAMMILL. I'd like to ask a question of Mr. Carter.

The previous witness, Mr. Williams, said that he felt that the major effort should be concentrated on the automotive gas turbine engine. He said the evidence that this is the automotive powerplant of the future is very strong. I gather that you wouldn't agree entirely with that.

Mr. CARTER, JR. No, I wouldn't.

Mr. HAMMILL. One of the assertions that he made was that almost every government study of alternative powerplants in recent years has concluded that the gas turbine is the leading candidate to replace the piston engine, is that true in your opinion?

Mr. CARTER, JR. That may be since many government studies have been based on steam technology developed in the 1920's and 1930's. I would also like to point out that there have been government appropriations both in California and by the Federal Government to build a steam engine, but so many times they put such timetable restrictions on the project that in order to meet that time schedule, companies do no have the time to devote, to developing a new system. They have to go with something that is pretty much already established. We try to get something done as fast as we can, but in the interest of coming up with something new or working out a better solution, we don't have a time schedule as such. We can take the time and get the job done right and then move on.

Mr. CARTER, SR. I have been in the steam business for 30 some years, and I have built several steam engines, and I recognized, 10 or 15 years ago that what we needed was a new approach to this steam engine. And one thing that was needed was a steam admission valve that would let an engine run at higher rpm's. High rpm's is something modern. Higher rpm's is something that didn't exist in a steam engine 30 and 40 years ago. If you are going to compete with a lightweight internal-combustion engine, you are going to need high rpm's. That is the first requirement. Also if you are going to be modern, you need to operate at high pressure. That means you will have to have a design that will operate at high pressure. At the very beginning, we realized this. The first 2 years, we were doing exploratory work. We were trying to find that solution, and we knew we had to have it before we could spend much money. That is what we were doing the first 2 years, developing the steam admission valve. After that we were ready to start spending money on building a steam car.

Mr. HAMMILL. Earlier witnesses, though, have mentioned the theoretical limits of steam. I would like to explore that further with you. Mr. Brown already brought it up. Your response, as I recall it, was along the lines that while there are theoretical limits, by the use of advanced technology, and so forth, you can achieve more within these limits.

Mr. CARTER, SR. Yes, sir.

Mr. HAMMILL. If there are, in fact, theoretical limits, however, then the best possible steam engine can only achieve a certain level of performance. Now, how would that level of performance compare with other alternatives such as the gas turbine?

Mr. CARTER, JR. I would like to answer that. Those theoretical limits were probably based on 1,000 degrees. That was the upper limit that previous technology would allow a reciprocating steam engine to run. We are now capable of operating our engines from 1,200 degrees to 1,300 degrees. Strictly from a layman's standpoint, if the steam wasn't more than just theoretically efficient, it wouldn't be used to power our large powerplants for producing electricity. The theoretical efficiency can be very high if you go to the higher temperatures and pressures. Our design enables us to go to these higher temperatures and pressures. One other point, the internal combustion engine is most efficient at full throttle. If you compare the best efficiency of the steam engine with the best efficiency of the internal-combustion engine, they are pretty close to one another but the internal-combustion engine under most driving situations operates at part throttle, maybe one-fourth of full throttle. Here the internal-combustion engine efficiency starts dropping off drastically, so that normally its operating condition is not at its peak efficiency, but something significantly less that that. The steam engine, on the other hand, can be designed where it operates under cruise conditions at its peak efficiency.

Peak efficiency of both systems would be very close to one another, but the fact that the steam system can operate in an automobile at peak efficiency, while the internal-combustion engine operates at less than its peak efficiency, gives us a very significant advantage just on that point. We can also operate at higher temperatures than what we are presently using. We are going to beat the internal-combustion engine. There is no question about it, just based on our test results and I know the engineers at EPA are also aware of our test results and the very easy areas for improvements. Our next car will unquestionably prove that point.

Mr. HAMMILL. In that regard, have you discussed with the research elements within the automotive industry, the Big Three, let's say, what you have done? Have you discussed your patent situation with them?

Mr. CARTER, JR. We have sent them a letter since our test results. We felt like it was meaningless to do anything before we had some good third party test results. We got a confirmation from Ford Motor

Co. that they had received our letter, and that they were looking into the matter. That is all we have received so far, and I am afraid that is all we will see. What I think may happen based on past history, is that some aggressive, progressive foreign car manufacturer will take what we got and start producing and bringing steam cars into the States and force Detroit by sheer economics to get serious. This is what happened to the Wankel engine and I would hate to think that is what may happen to steam, but it could.

Mr. CARTER, SR. I am not afraid. I hope that is what happens.

Mr. CARTER, JR. I would like to see the American companies do it first. I would just because I like the United States and what it stands for, but maybe that is the kind of pressure Detroit needs.

Mr. HAMMILL. By the way, the people in the automotive industry in Detroit aren't convinced that the Wankel engine is here to stay.

Mr. CARTER, JR. No; they are not. They spent $50 million for the right to produce it and then another $150 million for patent investigation and other research. I maintain they could have gambled just a tiny fraction of that on what we have done and come out much better.

Mr. CARTER, SR. That proves the automobile companies are not too smart or better. There were people 10 years ago that told them that this engine is not efficient.

Mr. HAMMILL. They still feel it is not efficient?

Mr. CARTER, JR. Yes, but they spent a little money to find out.

Mr. BROWN. Are there any further questions?

Mr. WINN. I have no further questions.

Mr. BROWN. Thank you very much, gentlemen. I assure you that you have provided the committee with a most interesting example of what American ingenuity can accomplish and we are very pleased to have you here this morning.

Our next witness is Mr. Robert U. Ayres, Vice-President of International Research and Technology Corp. We are very pleased to have you here this morning, Mr. Ayres, and we look forward to your testimony.

Mr. AYRES. Thank you very much. With your permission, I will read the statement and add some interpolations at points based on ideas that occurred to me since I read some of the other testimony and also I may, with your further permission, add a few comments at the end.

Mr. BROWN. You have heard the testimony of the two earlier witnesses and anything you care to say based upon that will be welcome, also, of course.

[A biographical sketch of Dr. Ayres follows:]

ROBERT U. AYRES

Ph.D., University of London, Vice President, International Research and Technology Corporation. Dr. Ayres is a pioneer in the rapidly growing field of technological forecasting and technology assessment, and an authority on environmental pollution and transportation technology. In 1962, Dr. Ayres joined the research staff of the Hudson Institute where he remained for five years before moving to Washington, D.C. in 1967 to become a visiting scholar at Resources For the Future, Inc. He is the author or co-author of several books: *Technological Forecasting and Long Range Planning*, *Aspects of Environmental Economics: A Materials Balance-General Equilibrium Approach*, with Allen V. Kneese and Ralph C. d'Arge, and *Alternatives to the Internal Combustion Engine*, with Richard McKenna. He has also published numerous articles and