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AN ELECTRIC AUTOMOBILE POWER PLANT SURVEY

A Talk Given

by

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at

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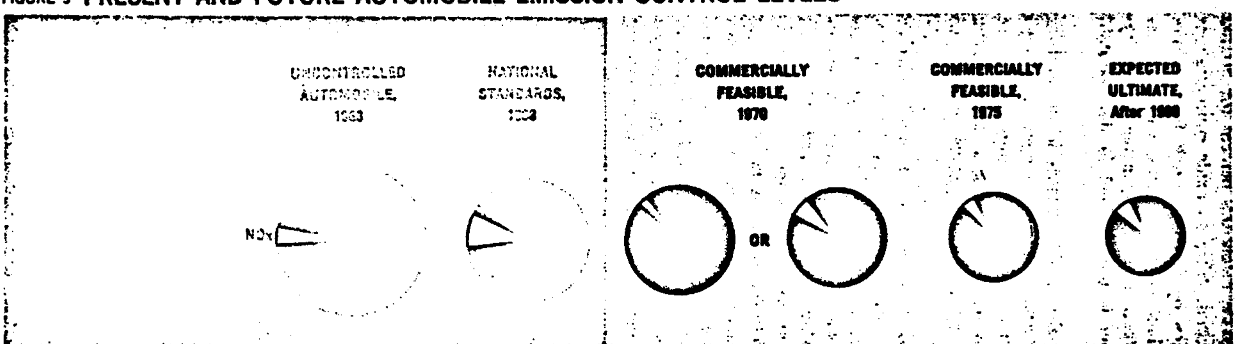
AN ELECTRIC AUTOMOBILE POWER PLANT SURVEY

This survey paper deals with material recently published as a result of considerable government, corporate and public interest in electric cars. Much of this interest stems from a concern over air pollution. However, a comprehensive study recently completed by the Commerce Department's Panel on Electrically Powered Vehicles (Ref. 1) points out that the technology for electric vehicles is not now adequate to permit production of an economically feasible electric car.

This survey paper discusses some of the incentives claimed for electric power train development, the competitive requirements and the status of current technology, the direction of research and development efforts; and it leads to a conclusion regarding the likelihood of success based on current published trends.

FIGURE 5 PRESENT AND FUTURE AUTOMOBILE EMISSION CONTROL LEVELS



EXHAUST	TYPICAL EMISSION LEVELS	ESTIMATED POLLUTION PER CAR/YEAR									Less Than	Less Than
HYDROCARBONS	900ppm	300 lbs.	275ppm	90 lbs.	275ppm	90 lbs.	180ppm	60 lbs.	50ppm	20 lbs.	25ppm	10 lbs.
CARBON MONOXIDE	3.5%	1700 lbs.	1.5%	750 lbs.	1.5%	750 lbs.	1.0%	500 lbs.	.5%	250 lbs.	.25%	120 lbs.
NITROGEN OXIDES	1500ppm	90 lbs.	1500ppm	90 lbs.	350ppm	20 lbs.	600-800 ppm	40 lbs.	250ppm	15 lbs.	100ppm	10 lbs.
CRANKCASE BLOWBY (hydrocarbons)		130 lbs.		none		none		none		none		none
EVAPORATION (hydrocarbons)		90 lbs.		90 lbs.		none		none		none		none
TOTAL		2310 lbs.		1020 lbs.		860 lbs.		600 lbs.		285 lbs.		140 lbs.

From -- The Automobile and Air Pollution: A Program for Progress, October 1967. Report of the Panel on Electrically Powered Vehicles. U. S. Department of Commerce.

Some incentives which are claimed to warrant considerable research and development on electric power trains, and which could ultimately lead to their production for small cars are:

(a) The ability to enter and operate in environmentally conditioned space with no emissions;

(b) Potentially lower maintenance and higher reliability;

(c) Lower and diminishing electric energy costs in the face of level or possibly rising gasoline fuel costs;

(d) Nearly competitive initial and lower operating costs.

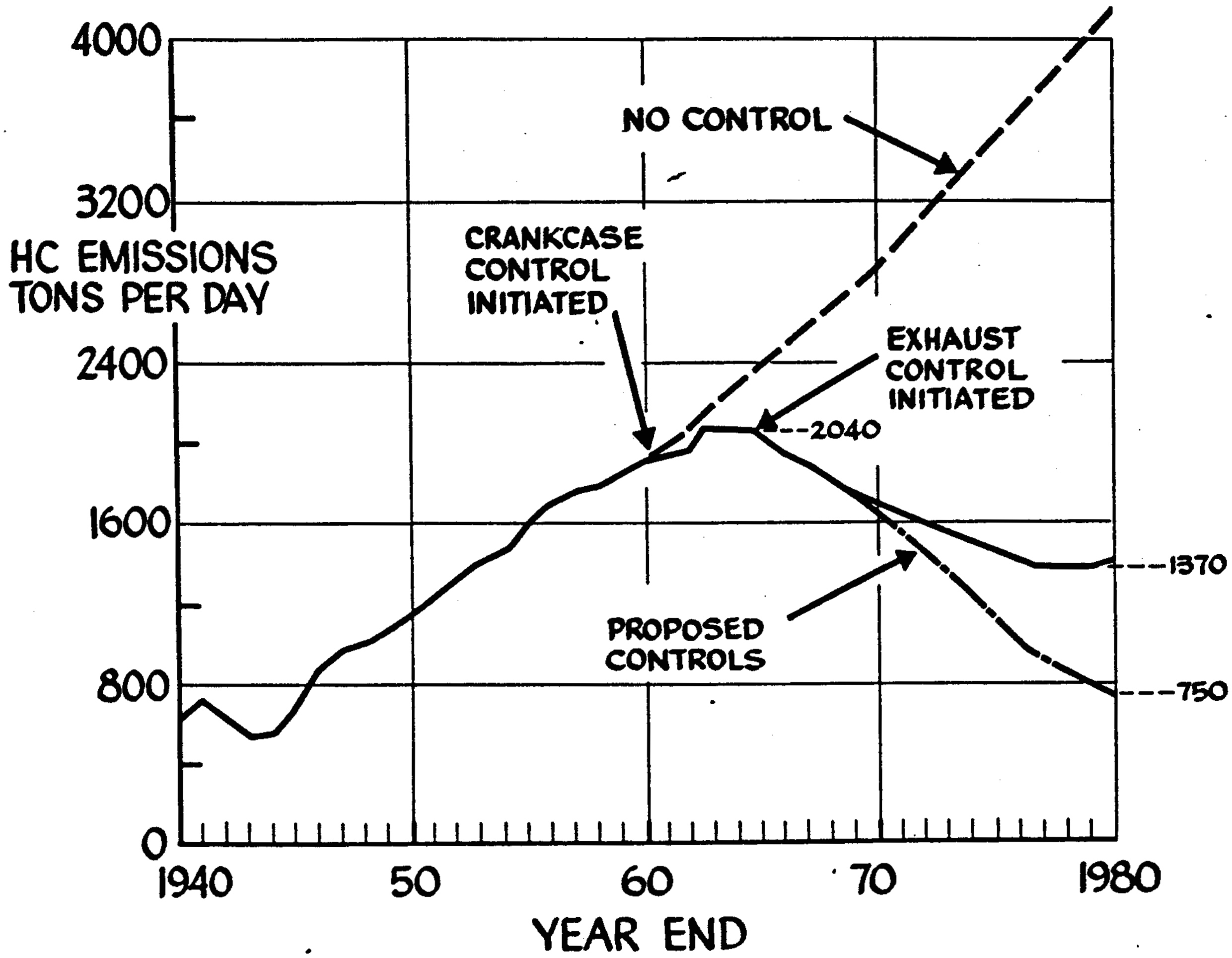
SLIDE 2

Some of the incentives claimed (Ref. 2) for electric vehicles are shown on this slide.

The first of these may seem strangely worded, but as shown on this slide, substantial reduction in conventional engine emissions are commercially feasible in time. Whether these projected levels are actually achievable is less important than the trend which is unmistakably toward lower emissions from the ICE, so much so that it really becomes the 100% emission-free character of the electric system which is important.

For instance, the effect of emission controls in Los Angeles is shown on this slide. As you can see, by 1980, the emissions are likely to be back to where they were in the '40s, in spite of a 4% per year increase in the number of vehicles.

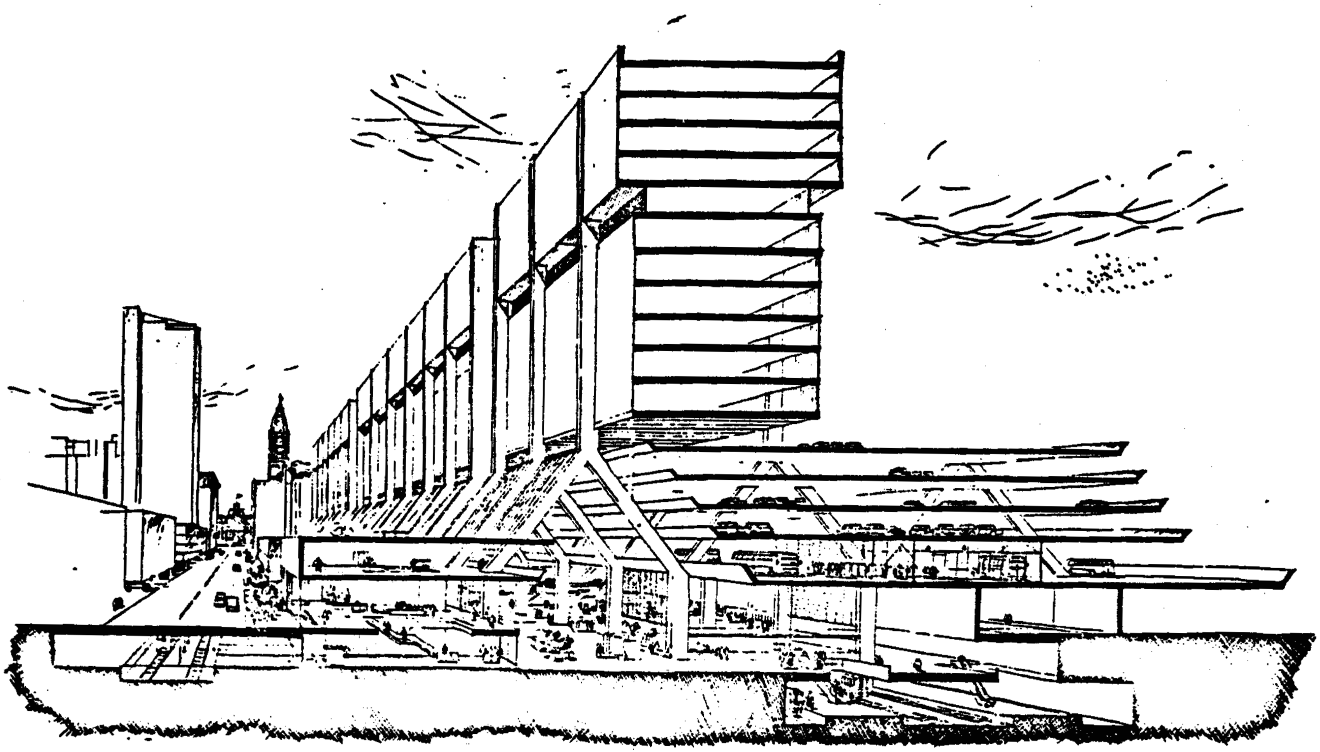
EFFECT OF CONTROL PROGRAMS ON HYDROCARBON EMISSIONS FROM MOTOR VEHICLES IN LOS ANGELES COUNTY



SLIDE 3

The ability to enter and operate in an environmentally conditioned space with no emissions is thought by many city planners (Ref. 3) to be a prerequisite to the construction of certain types of buildings and facilities in the downtown business district. Cost benefit analyses have not yet justified the added cost of emission-free power trains compared to the cost of ventilating the facilities; nevertheless, construction based on no ventilation is being planned, as shown in this slide.

This shows Philadelphia's Market East project (Ref. 4), where concourses are available which are environmentally controlled, and which could be used for vehicles if these vehicles had no emissions.



SLIDE 4

An incentive based on potentially lower maintenance and higher reliability is much more difficult to document, since electric automobiles of performance and utility comparable to conventional automobiles are not available.

Claims of reduced maintenance and high reliability for electric power trains are therefore generally based on studies of comparable gasoline and electric industrial trucks (Ref. 5). Let's spend a few moments looking into this comparison for the insight it might give.

This slide from "Industrial Trucks", Lead Industries Assoc., shows what I mean.

SO, TOTALING UP -- for a 4000 lb. Truck Rating

	Typical Gas	Example Electric
Cost to own, $/year	840	560
Cost to operate, $/year	1285	1163
Cost to maintain, $/year	4835	1938
TOTAL, $/year	6960	3661
	3661	
SAVING, $/year	3299 in favor of electric truck	

From: "Industrial Trucks", Lead Industries Assoc.

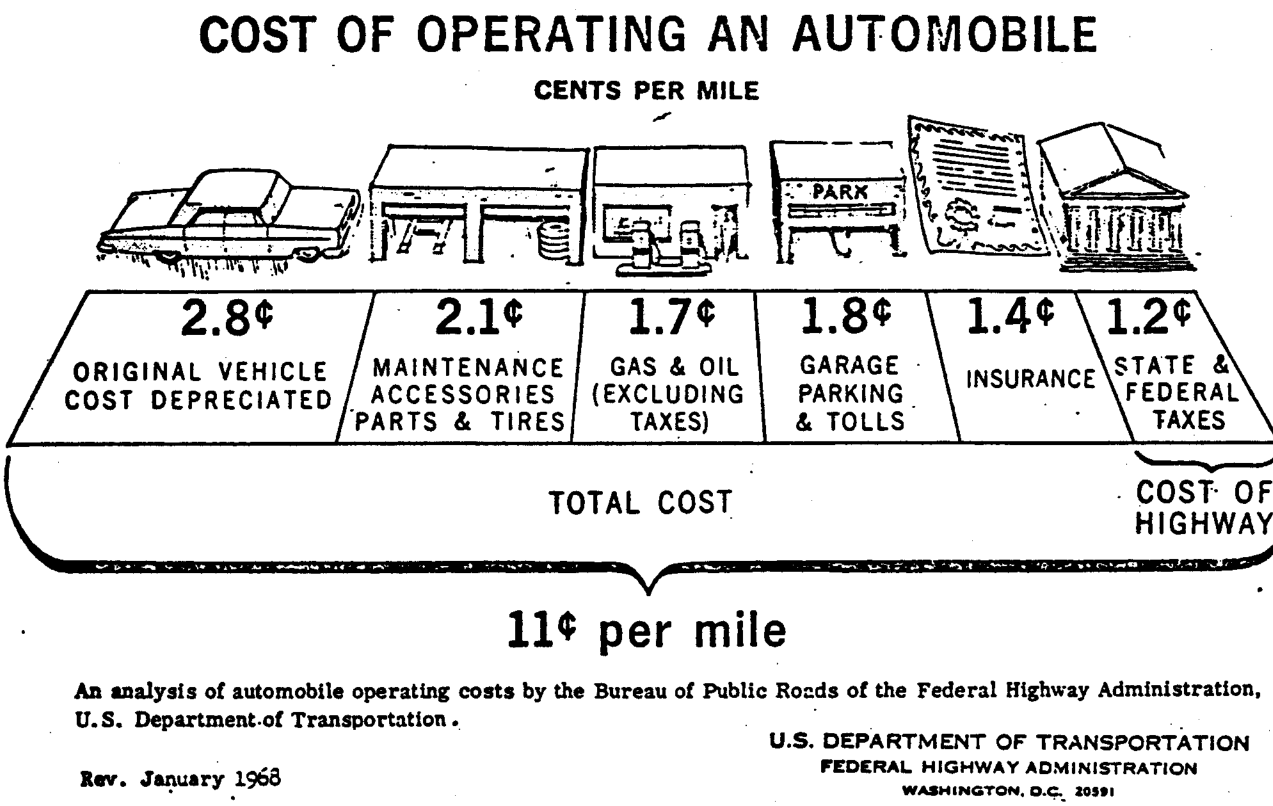
SLIDE 5

First, it should be understood that electric trucks are claimed to last twice as long as gasoline trucks. Therefore, in spite of the 30-50% higher initial cost of the electric exclusive of batteries, the cost to own per year is somewhat less than gasoline.

The cost to operate is strongly based on the number of hours used per year, which for such applications, is in the order of 4000 hours per year. This is an extremely important point, because depreciation on the batteries is the most significant portion of the electric's operating cost.

But the key to these claims is the cost to maintain the gas and the electric. Apparently, according to these figures, most of the savings claimed result from reduced maintenance, averaged over the life. First year maintenance costs (4000 hours of operation) for both types of power trains are much lower than the average and quite comparable to each other. It is in the later years that the electric shows an advantage.

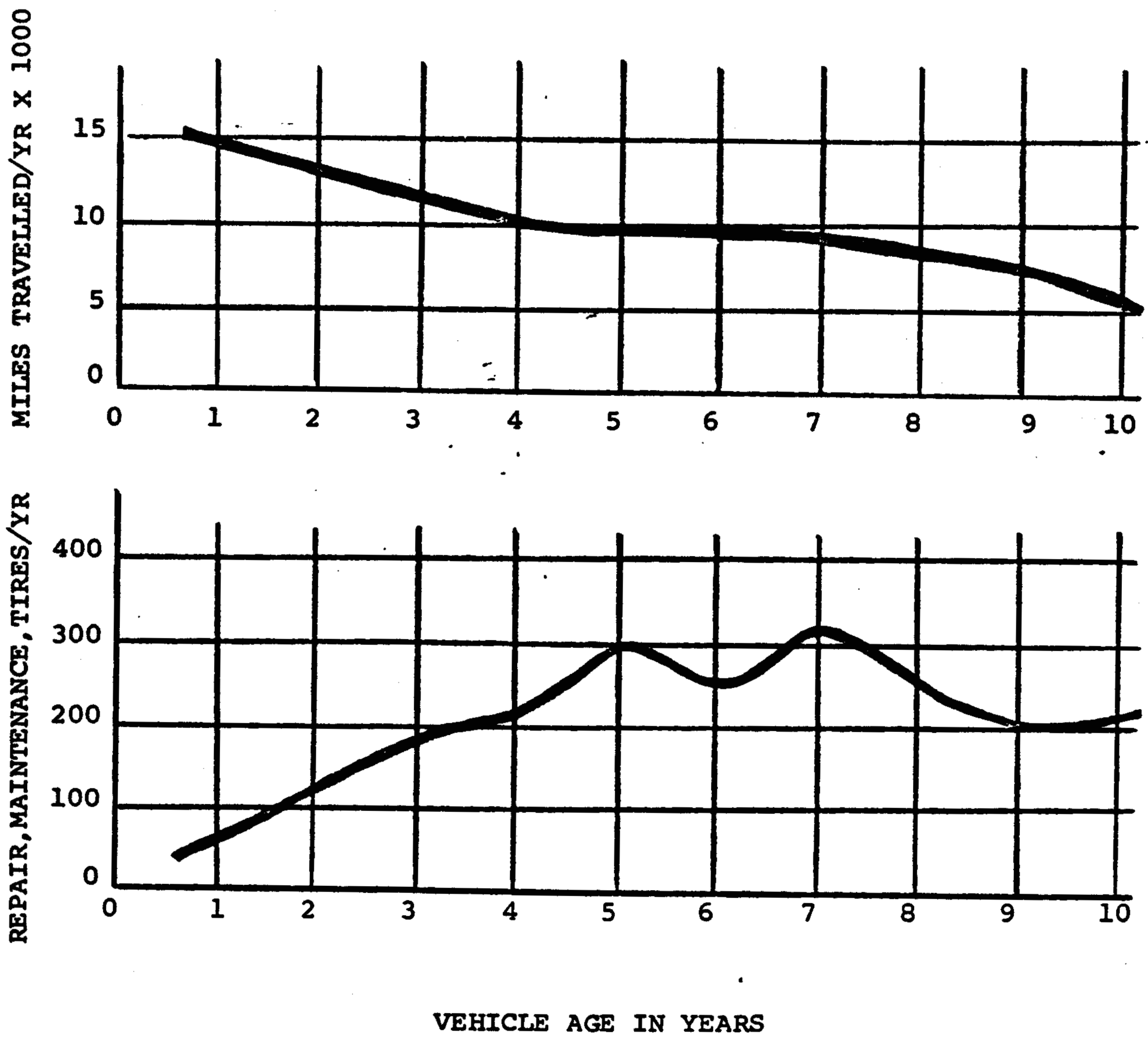
Relating this to the incentives for electric power trains for automotive applications, we must recognize that in the course of its entire life, an automotive power train operates for about 100,000 miles or approximately 4000 hours, and this is comparable to the first year of operation of an industrial truck.



SLIDE 6

The Department of Transportation (Ref. 6), on the other hand, recently published "Cost of Operating An Automobile." Their data indicates that the individually handled repairs and maintenance for individually owned autos are much less significant than those of the fleet-serviced industrial trucks. In fact, a most significant point is that depreciation is 25% of the total cost.

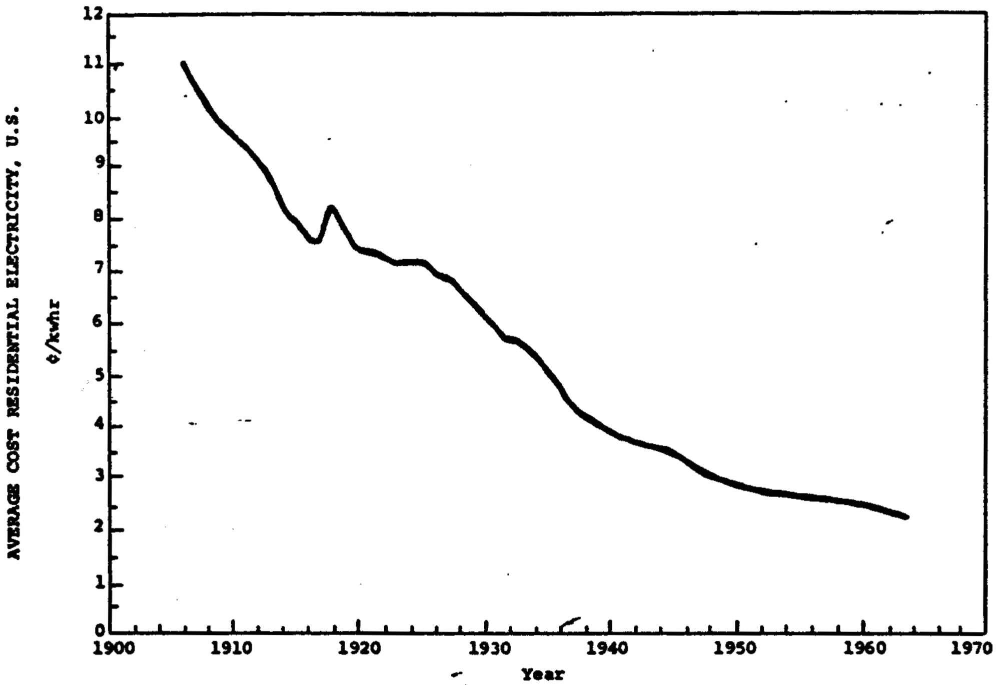
To be a little more precise, let's look at a plot of the data contained in this Department of Transportation publication, as shown in this slide. As you can see, repair, maintenance, tires, etc., per year for the average $3000 vehicle increases rather slowly over the first five years of life before leveling out, and this was based on data prior to 5-year, 50,000-mile warranty automotive service.



SLIDE 7

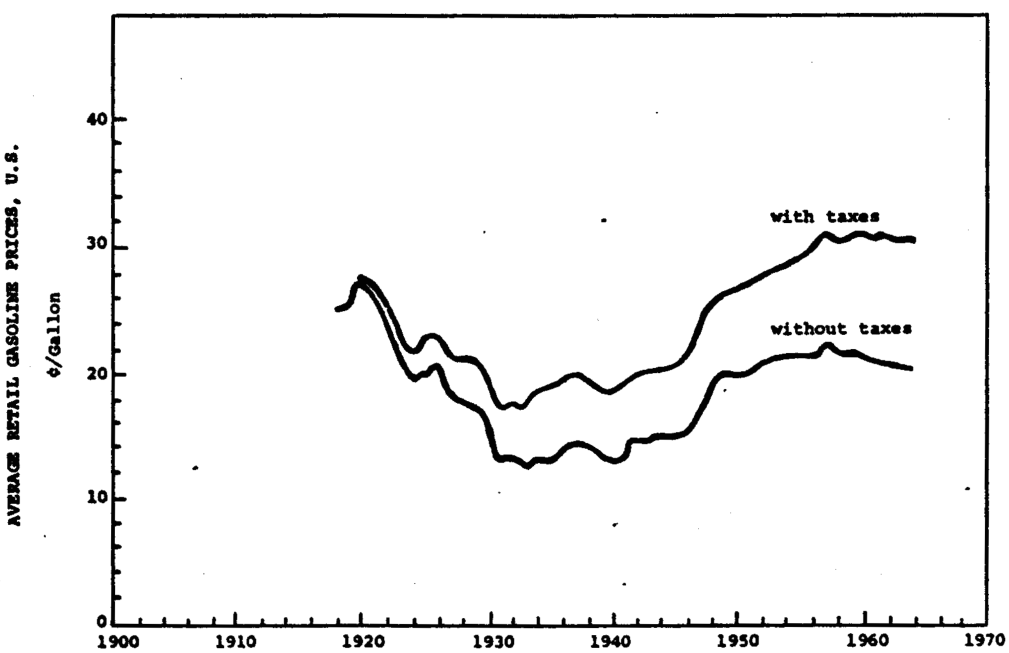
It would appear then that the gains in reduced cost of maintenance, which is an important incentive in the choice of power trains for an industrial truck are not likely to be as significant in the automotive application.

Lower and diminishing electric energy costs based on the average cost of residential electricity in the U.S. are shown in this slide (Ref. 7).



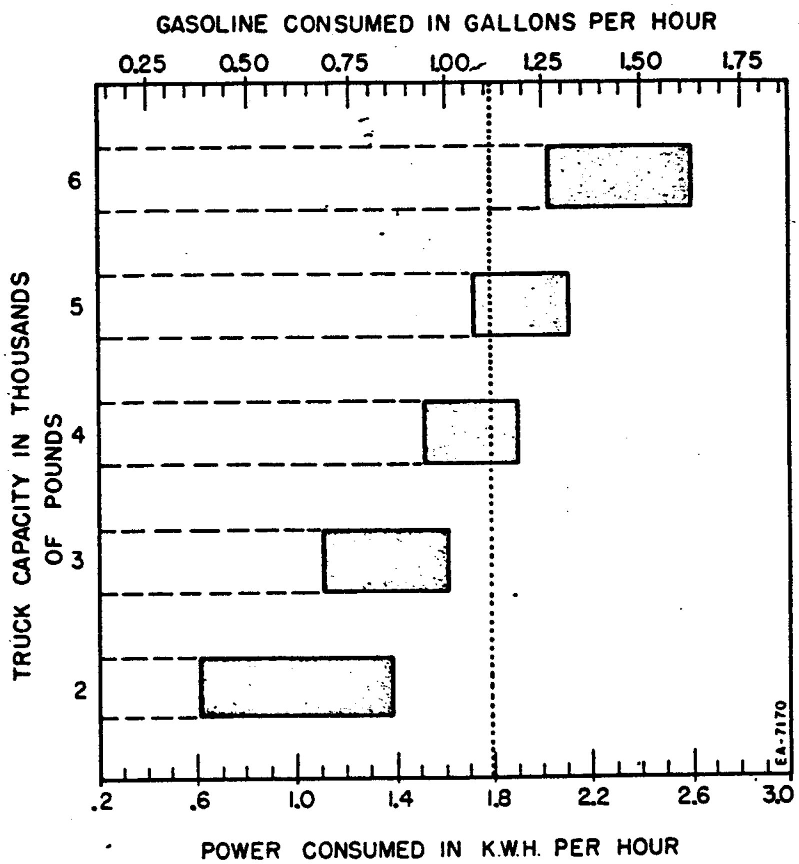
SLIDE 8

Gasoline fuel costs, however, can be considered level or possibly rising, as shown on this slide.



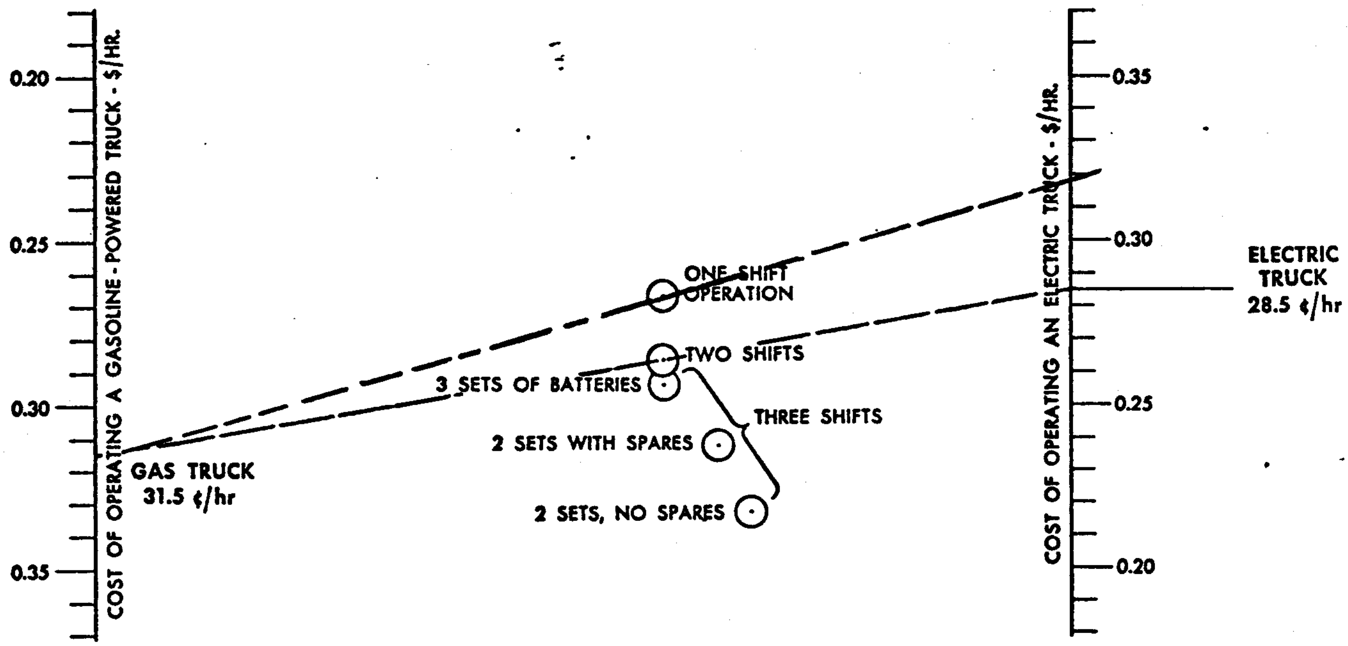
SLIDE 9

This slide from another comparison of Industrial Trucks by the Electric Storage Battery Company (Ref. 8) indicates that for forklift truck type duty cycles, 1.6 kwh of consumed battery power is required to do the same amount of work as 1.0 gallon of gasoline. Even at 50% electric efficiency, and at the rates indicated on the previous slide, the electric shows a clear advantage for this type of stop-and-go operation. However, much of the significance of this energy cost saving advantage is lost in the duty cycle of the average automobile running at fairly constant speeds.



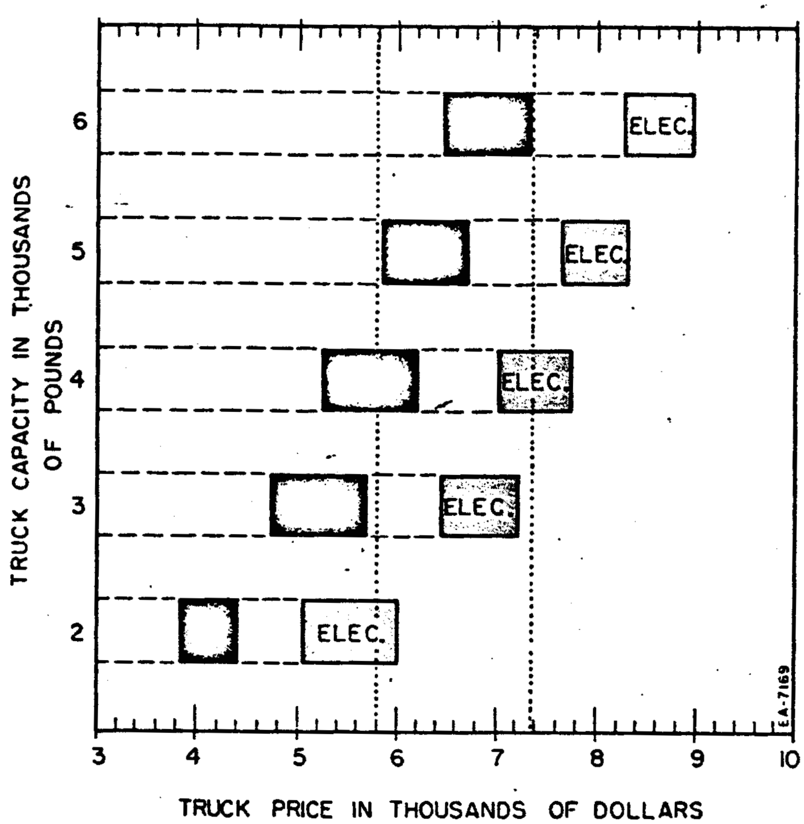
SLIDE 10

A further point is that the more rapid depreciation of the battery, compared to the rest of the vehicle, must somehow be factored into the operating costs. These costs are strongly dependent on the battery usage per day. In the previous example of the gasoline vs electric industrial truck on two shifts, the total costs/hr are close, as shown on this slide. On one shift, they are almost identical. If an appropriate plot were made of 1 hr/day operation, the electric would exceed the gasoline costs, and this is precisely the duty cycle typical of an automobile.



SLIDE 11

As was indicated in the Department of Transportation analysis of the cost of operating an automobile, depreciation is 25% of the total cost. It follows then that the public sale of cars with electric power trains depends in large measure on the ability to produce them at competitive initial costs.

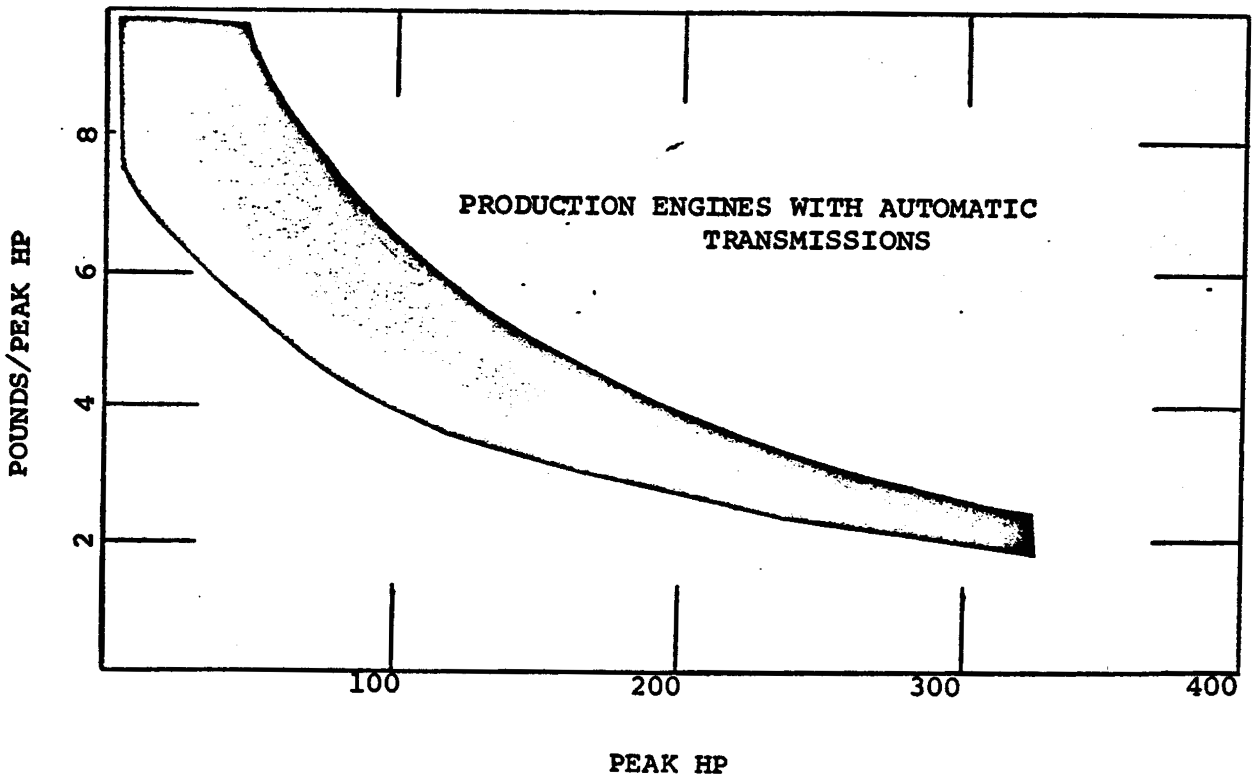


SLIDE 12

As shown on this slide, again from Electric Storage Battery Co., the cost of electric industrial trucks (without battery) is about 30% higher than the gasoline equivalent, so that much development attention must go toward reducing the cost of the electric drive components.

In summary, relative to incentives: --Electric power trains have special advantages, and may be competitive in many applications, particularly those involving high usage per day. The currently successful applications are at low peak power and low energy drain rates in stop-and-go operation for 8 - 24 hours per day.

Let me get on now to a discussion of the technical and economic competition between an internal combustion engine-automatic transmission (ICE-AT) and an electric power train for automobiles. This slide shows the band of weights per peak hp as a function of hp for a variety of production engines with automatic transmissions. Most of the more rugged power trains fall near the upper limits of the band.



SLIDE 13

The typical ICE-AT for small foreign cars weighs about 7 to 10 lbs/peak hp at 40 hp. For full-size conventional cars at 200 hp, the ICE-AT weighs 3 to 4 lb/peak hp.

This slide lists these weights of automotive power trains with automatic transmissions for small foreign cars, and their list price based on available data reduced by 25% to correct for current limited production. The result is a list price of $12 to $15/hp at a 40 hp rating. Full-size conventional cars at 200 hp in current large production have a list price of $4 to $5/hp. The relative list price per peak horsepower of the power train for full-size conventional cars is therefore of the order of 1/3 that of small cars. The high initial cost anticipated for electric power trains is more in line with the power train costs of small cars than of full-size cars, and represents an important factor in choosing an initial passenger car application for electric power trains. Much current work and this paper are therefore focused on power trains for small cars.

Published Data on Alternate Power Trains	Published Weight in lbs/peak hp	Published List Price $/hp
Small foreign car 40 hp ICE-AT*	7 - 10	12 - 15#
Full-size car 200 hp ICE-AT	3 - 5	4 - 5

*ICE-AT - internal combustion engine-automatic transmission.

#For comparison purposes, the published list price is shown reduced by 25% to compensate for current limited production.

SLIDE 14

Published Data on Alternate Power Trains	Published Weight in Lbs/peak hp	Published List Price $/hp
Small foreign car 40 hp ICE-AT*	7 - 10	12 - 15
Full-size car 200 hp ICE-AT	3 - 5	4 - 5
**A hypothetical electric power train		
DC electric motor	3.5 - 4	4.5 - 6
DC controls	.7 - 1.3	4.5 - 7.5
Lead-acid battery	8 - 10	4.2 - 4.8
TOTAL	12.2 - 15.3	13.2 - 18.3

*ICE-AT - internal combustion engine-automatic transmission.

**Based only on peak power capability of the Pb-acid battery. Battery range 5-15 miles and 200-400 cycles life at room temperature.

SLIDE 15

Published Data on Alternate Power Trains	Published Weight in Lbs/peak hp	Published List Price $/hp
Small foreign car 40 hp ICE-AT*	7 - 10	12 - 15
Full-size car 200 hp ICE-AT	3 - 5	4 - 5
**A hypothetical electric power train		
DC electric motor	3.5 - 4	4.5 - 6
DC controls	.7 - 1.3	4.5 - 7.5
Lead-acid battery	8 - 10	4.2 - 4.8
TOTAL	12.2 - 15.3	13.2 - 18.3
***Potential electric power trains		
Electric motor	1 - 4	1.5 - 6
Controls	.7 - 1.5	4.5 - 10.5
Battery	5 - 15	8 - 30
TOTAL	6.7 - 20.5	14 - 46.5

*ICE-AT - internal combustion engine-automatic transmission.

**Based only on peak power capability of the Pb-acid battery. Battery range 5-15 miles and 200-400 cycles life at room temperature.

***Based on published, predicted, characteristics of potentially available components now in research and development. Battery range of 50-150 miles, and thousands of cycles.

SLIDE 16

Let's next discuss why we must anticipate higher initial costs for electric power trains. A hypothetical near term DC electric power train in the 20-50 hp size, such as might be appropriate for small cars, indicates a motor weight of 3 to 4 lb/hp, and a list price of about \$4 to \$6/hp, as shown on these additions to the previous slide. Controls weigh about 1 lb/hp, and would have a list price in quantity production of \$4 to \$8/hp (Ref. 9).

For the purposes of illustration, let's consider an unrealistic battery system based solely on the peak power capabilities of lead-acid batteries. This battery would have a list price of \$4 to \$5/hp, and weigh 8 to 10 lb/hp for 5 to 10-second discharge intervals (corresponding to acceleration intervals) at room temperature (60° to 80°F). The combined weight of this hypothetical DC system is then 12 to 15 lb/hp with a combined list price of \$13 to \$19/hp. These results would be much less favorable if this hypothetical system were designed for any reasonable range or performance in the actual environment. If the energy density of lead-acid batteries, which is something in the order of one hundredth to two hundredths of a horsepower per pound, could be substantially improved, this type of system could be reasonably competitive. This low energy density limits the range of the vehicle and the cycle life of the battery. In addition, at lower temperatures, the weight/hp of Pb-acid batteries is almost doubled.

For potential electric power trains shown here, the AC motor and inverter controls promise reduced weight compared to the DC system. It is anticipated that eventually the AC motor can be built at about 1 lb/hp, but the inverter controls -- the more expensive part of the system -- are likely to be in the order of 1½ lb/hp (Ref. 10). At relative values per pound comparable to a DC machine and its controls, the AC system seems unlikely to reduce costs in the low horsepower sizes for small cars.

As has been reported in the literature recently (Ref. 11), Na-S, Li-Cl_2, and probably a host of other batteries under study, are projected to provide an energy density of at least one-tenth horsepower per pound and provide a reasonable range for vehicles using them, while simultaneously achieving a power density at least as high or higher than lead-acid batteries. Papers describing this research, however, indicate many technical problems to be solved before they can be considered in a production status. Estimates range from a few years to 10-15 years before they can be considered operational. In addition, proponents of these advanced research batteries readily admit that they cost too much. These energy sources are projected to contain materials and/or require manufacturing techniques which may, according to their proponents, result in the quantity production prices shown.

It is obvious, then, that the new battery systems at best are just competitive and possibly may result in much higher costs than the already marginal lead-acid battery system. This is an extremely important point, and one which I would like to leave with you, because there is a strong tendency to drive toward meeting performance requirements without adequate consideration of the economics of commercial production.

Further, let me remind you again that even if we can meet the competitive requirements for small cars, it will be necessary to reduce these costs by a factor of 3 in order to consider competing with the internal combustion engine-automatic transmission for full-size passenger cars.

Another tack being taken to augment the potential power level deficiencies of some of these batteries are all-electric hybrids. These are combinations of high-energy density batteries or fuel cells with high-power density batteries combined to take advantage of the best features of each. Such combinations which are being studied include lead-acid and zinc-air, Li-NiF_2 and Bipolar Ni-Cd, Ni-Zn and zinc-air, and others. In these cases, the lead-acid, Ni-Zn or Bipolar Ni-Cd batteries provide peak power requirements, while zinc-air and Li-NiF_2 batteries provide the energies for recharging the peak power batteries, as well as power for cruising. In the main, as currently envisioned, these still do not circumvent the high cost associated with the individual battery, and therefore may not be competitive for cars except for special applications.

Heat engines are also being studied in combination with batteries to overcome energy level deficiencies by recharging the batteries and/or providing some additional power to the wheels in the manner of this, the Woods Dual Power Car (Ref. 12).

Runs on Gasoline Power Alone

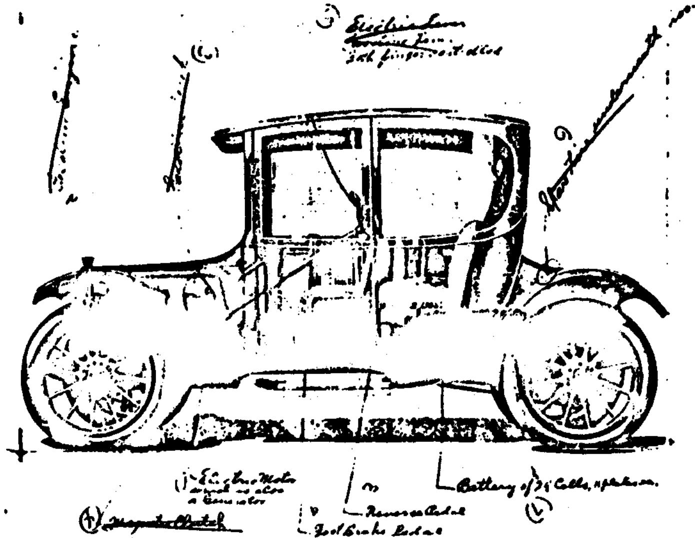
WHILE the two power elements employed in the operation of this car are electricity and gasoline, one supplementing and augmenting the other, it may be run on gasoline power alone.

At any position of the electric lever the gasoline lever may be advanced, which instantly starts the gasoline motor.

As the gasoline lever is pushed forward it causes the car to be operated more on the gas and at a certain point it will operate as a straight gasoline car, neither charging nor discharging the battery. With a slight variation of the relative position of the two levers the battery may be charged at will.

Here you have a gas car with the electric's simplicity, luxuriousness, ease of control, and reliability. And with the further advantages that there are no clutches to throw in, no gears to change, that fuel consumption is minimized, and that the electric equipment will not allow the gasoline motor to stall under any conditions.

A gasoline motor with an enormous horse power is extravagant because maximum power is seldom used. The gasoline motor of the Woods Dual-Power, supplemented by the electric motor as occasion requires, accomplishes everything that is desirable in a gas car.



Runs on Electric Power Alone

UNLIMITED mileage and adequate speed are features of the Woods Dual-Power. While retaining all the best features of the electric, the battery is charged or discharged at will or automatically under simple conditions while the car is running, reducing maintenance expense by 75% and making it possible to travel any distance, storing electricity or using it for power as required.

A simple movement of the finger-controlled lever on the steering wheel starts the car on electricity and will drive up to twenty miles an hour on electric power alone, the current being obtained from the battery while at its greatest efficiency, as its capacity is always kept within the safety zone, greatly increasing its life.

In braking and going down grades the retarding process is accomplished by braking through the motor which becomes a generator and charges the battery. This power or energy is thus conserved whereas it would be lost by braking through the bands of the rear wheels which further causes frequent expensive renewals of brake linings.

The Woods Dual-Power is more efficient than a straight Electric Car and yet has the advantages of the Gas Car and the combined utility of both.

Runs on Both Powers at Same Time—Maximum Efficiency

THE powers of electricity and gasoline may both be employed at the same time in the Woods Dual-Power. This ingenious combination creates the most astonishing results.

—A self-charging, non-stalling two-power car with unlimited mileage, adequate speed, and greatest economy.

It makes an Electric Car with unlimited mileage and 40% greater speed.

It makes a Gas Car without gears, levers, or clutch pedals and reduces to a minimum jars, jolts, and vibration.

In this two-power car, then, we have in addition instantaneous acceleration, finger control of starting, stopping, an unlimited number of speeds, operations reduced a hundred fold, cost of maintenance lowered by 75%, efficiency and utility increased 200%, outside charging plants eliminated and an enormous time saver.

And when you have compared the foregoing with any straight Electric or Gas Car you ever saw—

—Then add ease of control, noiseless movement, easy riding, refinement, luxurious appointments.

—And best of all, add contentment of mind—the thought that power is continuous—a constant stream of unfailing, smooth-flowing power.

Two small finger levers on the steering wheel control the entire operation of the car—starting, braking, stopping. One regulates the electric current, the other the gasoline.

Retarding of the electric lever acts as a most effective electric brake through the motor which then becomes a generator and charges the battery. The same results may be obtained by the simple movement of the foot pedal without touching the electric lever and this foot-brake as it is pushed farther becomes a mechanical brake.

The marvelous achievements of the Woods Dual-Power Car place it beyond competition.

No one power car can combine the simple efficiency, reliability, ease of control, serviceability, economy of up-keep.

It is at once the car of luxury and the car of service, the one that is always ready — the dependable car.

BRIEF DESCRIPTION—The body is aluminum panel construction, trimmed luxuriously, coupe design, with seating capacity for four persons. Artillery wheels are standard equipment. These are equipped with Silvertown Cord Tires, 34 x 4. Wheel base is 110 inches. All necessary tools are furnished and provision is made to carry an extra tire under the rear hood.

An exclusive design of whipcord in combination of black and white color or leather trimmings are regular. Samples of trimmings upon application.

Price, $2650 F. O. B. Chicago. Wire wheels and special painting and trimming specifications will be furnished at a small extra cost.

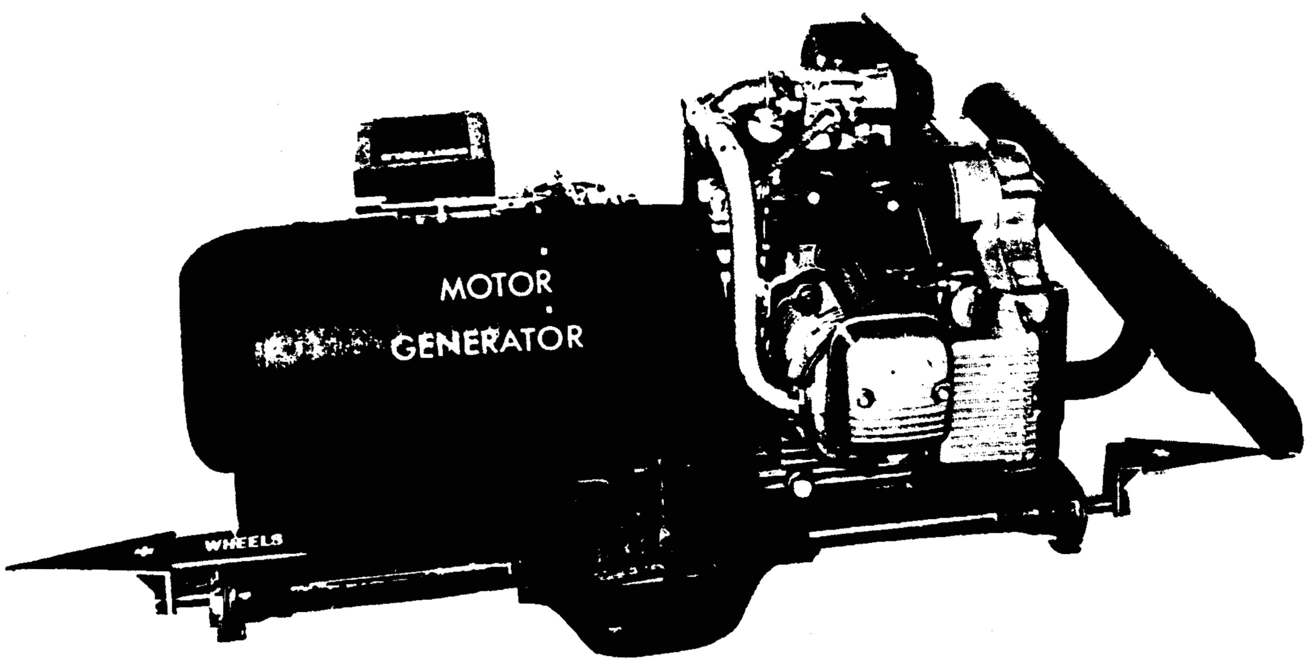
Those interested in technical details should consult the nearest dealer or write direct to the company.

A beautiful book with numerous illustrations and complete specifications will be sent upon request.

SL28 17

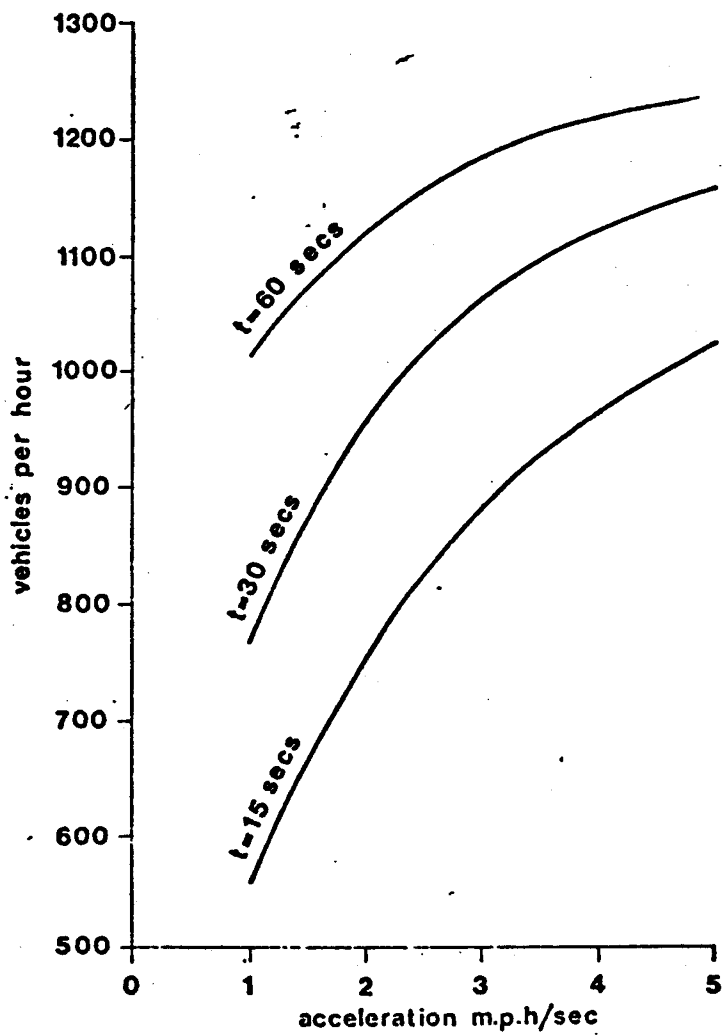
This vehicle, built in 1917 in limited quantities, exhibits many of the characteristics considered desirable in today's hybrid engine studies. Because of the production availability of small internal combustion engines, the heat engine-electric hybrid may be able to achieve adequate performance at reasonable cost in the near term for small cars. However, its advantage over conventional power trains is strongly dependent on the requirement for some emission-free range, and the initial price penalty we are prepared to pay for this capability.

One system at the 40 peak horsepower level analyzed for the Department of Housing and Urban Development's "Minicar" resulted in a weight of about 18 lb/peak hp (Ref. 13). This is substantially heavier, and was more expensive than what could be accomplished with the straight internal combustion engine and automatic transmission.



SLIDE 18

One of the requirements for the power train in this study is to allow the vehicle to operate in mixed traffic on streets and urban expressways to 55 mph without impeding traffic flow. As shown on this slide, this requirement may be expressed in terms of intersection flow (Ref. 14). This curve relates the acceleration capability to the traffic flow through an intersection. As you can see, in order to reach the knee of the curve for reasonable green light time, an acceleration average of 3 to 4 mph/sec is required. A vehicle accelerating at 4 mph/sec would reach 40 mph from a standing start in about 10 seconds.



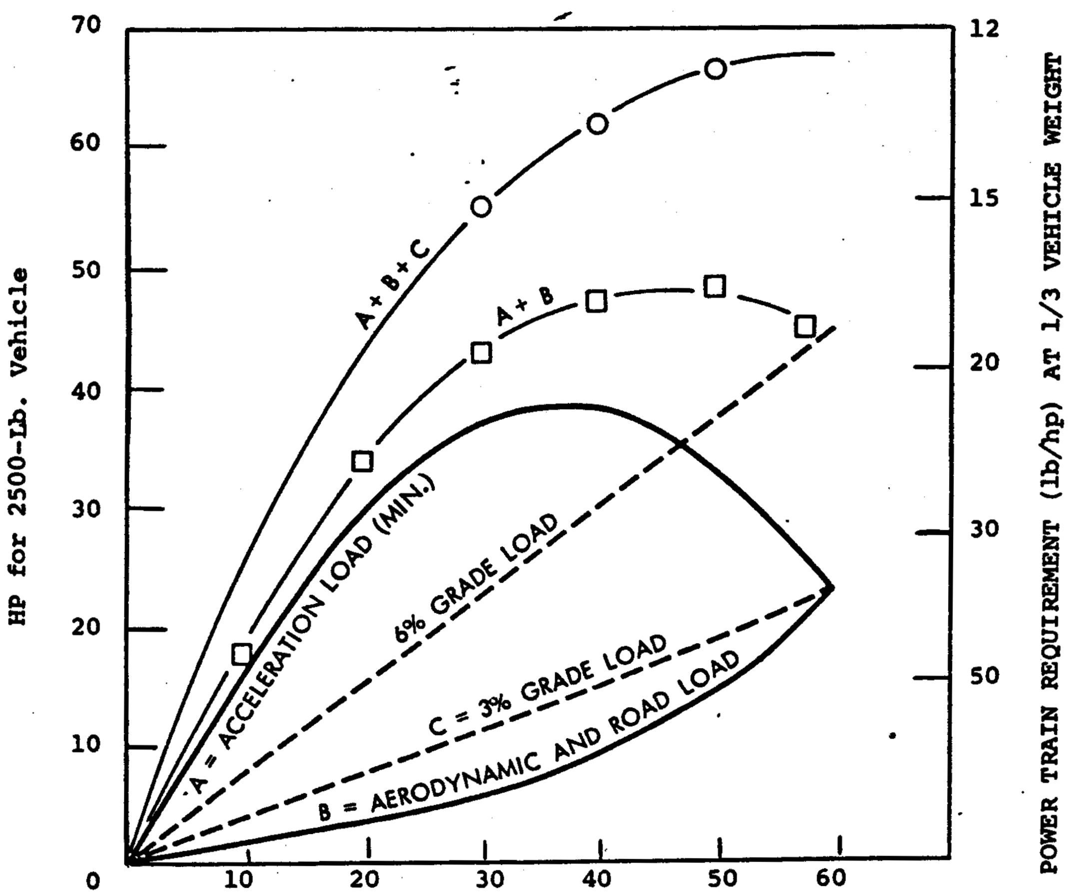
Simplified theoretical effect of acceleration at a traffic light controlled junction (t = green light time)

SLIDE 19

An average acceleration of 4 mph/sec to 40 mph for a 2500 lb. vehicle results in a minimum acceleration power requirement as shown in Curve A of this slide (Ref. 15). This is in addition to the aerodynamic and road load power shown as Curve B. The combined power required at the wheels for operation on a level surface is then Curves A + B. If the vehicle must accelerate up a 3% grade, the required power is shown on Curves A+B+C.

By assigning a percent of the gross vehicle weight to the power train, its weight per unit hp requirement may be determined. For instance, as shown on the scale at the right of the slide for a power train 1/3 the weight of the vehicle, the performance characteristic (A + B) establishes a requirement of 17 lb/hp.

MINIMUM POWER REQUIREMENTS FOR LOW SPEED
URBAN MIXED TRAFFIC OPERATION



Speed in Miles Per hour

SLIDE 20

Recently, the University of Pennsylvania (U. of P.) also established other requirements for an urban vehicle power train, shown on this slide, along with a preliminary and qualitative evaluation of a variety of alternate power trains at the 40-hp level. In addition to the acceleration requirement just mentioned, the range of the vehicle was set at between 50 and preferably 100 miles, which allowed home-to-work travel, as well as intra-Central Business District operation. The U. of P. also indicated that in order to reduce costs and make the vehicle most competitive, it was preferable to consider power trains which were available in mass production, and that any power train to be considered had to be capable of being modified to the lowest levels of emissions which might likely be established. This was tentatively set at about 10% of the 1965 full-size passenger car emission.

POWER PLANT	Acceleration 0-40 mph 10 sec	Range 50-100 Miles	Mass Produced Components	Very Low Emission Modifications Possible	Some Emission-Free Range	Provision For Heat & Air Conditioning
ICE	P.S.	P.S.	P.S.	P.S.	P.U.	P.S.
Diesel	P.S.	P.S.	P.S.	P.S.	P.U.	P.S.
Stirling	P.S.	P.S.	P.U.	P.S.	Q	P.S.
Rotary	P.S.	P.S.	P.S.	P.S.	P.U.	P.S.
Steam	P.S.	P.S.	P.U.	P.S.	Q	P.S.
Turbine	P.S.	P.S.	P.U.	P.S.	P.U.	P.S.
All-Electric	P.S.	P.U.	P.S.	P.S.	P.S.	P.U.
Hybrid ICE-Electric	P.S.	P.S.	P.S.	P.S.	P.S.	P.S.

P.S. = Probably Satisfactory
P.U. = Probably Unsatisfactory
Q = Questionable

SLIDE 21

In addition, the representative of the Planning Commission of the City of Philadelphia, who exercised a strong influence on the study, insisted that emission-free range might be required. Provision for heat and air conditioning was also established as a requirement. Estimates were made of the weight of alternate power trains and their relative prices in large scale production. When you consider that Green on this chart stands for "Probably Satisfactory", Yellow, "Questionable", and Red, "Probably Unsatisfactory", it becomes clear that the hybrid electric power train has a minimum number of negative features associated with it, the prime one being that it costs more than the internal combustion engine-automatic transmission alternative. On the other hand, the only drawback to the ICE is the requirement for some emission-free range.

This is a tabulation of recently announced electric vehicle characteristics as published by the respective developers (Ref. 16-21).

As you can see, the first four of these vehicles are small in size and light in weight. The Mars II contains 1900 lb. of batteries to achieve its very respectable performance and range. The Electrovair utilizes silver-zinc batteries to show that performance comparable to some conventional cars is technically feasible, even though it is economically impractical.

PERFORMANCE CHARACTERISTICS

	GENERAL ELECTRIC	FORD "COMUTA"	WESTINGHOUSE "MARKETTE"	AMER. MTRS. "AMITRON"	MARS II	GM "ELECTROVAIR"
Dimensions:			18x5.7/5.0-8		Std. R10 Renault	
Length	130"	80"	116"	85"	167.5"	183.3"
Width	56"	49.5"	54.5"	69½"	60"	69.7"
Height	59"	56"	60.5"	46"	55.5"	51.2"
Wheelbase		53.5"	76"		89"	108"
Turning Circle		18'	11'			37'
Curb Weight	2300 lb	1200 lb	1730 lb		4160 lb	3400 lb
Seating Capacity	2 adults + 2 children	2 adults + 2 children	2-passenger	3-passenger	5 passenger	6-passenger
Energy Source	920# Combination Pb-acid + Ni-Cd	4-12V 85 amp hr Pb-acid @ 1 hr rating	12-6V 217amp hr Pb-acid 792#	Bipolar Ni-CD + Li-NiF_2	1900 lb Pb-acid 30 Kwh	680 lb Silver-Zinc
Controls	Solid State	Solid State	Resistance or Solid State		Voltage Switching	SS Inverter
Motor	DC	Two 24V DC 5 hp peak ea	Two 36V DC motor 4-5 hp peak ea		DC, 15 hp Continuous	100 hp peak AC induction
Maximum Speed	55 mph		25 mph	50 mph	60 mph	80 mph
Range	100-200 mi @ cruising speed of 30-35 mph	40 mi @ 25 mph	50 mi per charge	150 mi	70-120 mi (normal city driving)	40-80 miles
"In town" Range	40-50 mi		Slightly less than maximum	50 mi	70-120 mi	
Transmission	Transaxle to front Wheels	No Clutch	Silent chain drive		Manual, 4-speed forward	
Acceleration	3.75 mph sec		0-25 mph 12 sec		0-40 mph 10 sec	0-60 mph 16 sec

March 1968

In summary, let me emphasize again that research and development must be oriented toward improved performance with cheaper than current state-of-the-art components, and that improved performance will not by itself, provide the competitive edge over the internal combustion engine-automatic transmission. This is reinforced by the increasing likelihood that the emission characteristics of the internal combustion engine can be improved to meet national standards for a healthy environment at reasonable cost. In spite of the many incentives, which may ultimately lead to production of electric power trains for automobiles, no electric power train has been described in the literature which is projected to be competitive in all respects with the ICE, except for special purpose applications and requirements.

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