THE "ULTIMATE" WHEELED CONVEYANCE (Part 2)

In Part 1 of this article we proposed the use of nuclear, thermal or chemical "direct conversion" units of small size to provide electricity to power the home and the car of the future. Individual cells of each of four different types were diagrammed and explained and, for convenience, were called "black boxes". The "ultimate" wheeled conveyance was described as a high speed electric car, designed to be powered by one of the black boxes. The history of electric vehicles was outlined from 1893 to the present and a brief reference was made to Walter Baker's early electric racing cars, each of which reached speeds in excess of 100 miles an hour. Three proposed production models of electric vehicles were also discussed.

In this Part 2 of the article we shall take up the most recent developments in the field of direct conversion black box devices and take another look at the remarkable early electric racing cars. The problems which must be solved to permit conventional electrically propelled vehicles to meet today's demands will be discussed and solutions will be proposed. The latest developments in electric vehicle design will be covered, together with data on operating and maintenance costs. Finally, we shall present some electric car design data, complete with formulas and equations, for the benefit of those do-it-yourself addicts who requested them.

As for black box developments, much has been accomplished since the publication of Part 1 of this article. Almost before the ink was dry, we were bombarded by magazine articles, news items and publicized demonstrations of nuclear, thermal and chemical (fuel cell) converters. Articles in "Electrical Engineering" and "Electrical World" on successful fuel cell prototypes appeared almost simultaneously in October 1959. Following this, in short order, one manufacturer successfully demonstrated an actual fuel cell powered electric farm tractor which used propane gas as the fuel, instead of hydrogen. Then General Electric announced a new thermal (ionized gas) type of direct conversion device, called the "Magnetohydrodynamic" (MHD) converter (Figure 1). Another research laboratory designed and tested a hollow tube type thermionic emission converter using the hot gases of a rocket or jet exhaust, instead of nuclear energy, as the heat source. Still another designed and tested a thermal energy converter efficient enough to make practical use of a coal or oil heat source for direct conversion to electrical power.

In short, all the types of direct conversion devices covered in Part 1 of this article have now been tested or demonstrated to the public. With all of these conversion units, usable quantities of direct current electric power, suitable for an electrically propelled "ultimate" wheeled conveyance are now, ostensibly, possible. One article stated that the fuel cell source of power for electric tractive vehicles is "practical now"

We received quite a few requests for additional copies of the BULLETIN article and for additional information. While this was pleasing, the speed with which these new black box developments appeared gave us a sobering jolt. Perhaps the direct conversion power source will be ready before a practical high speed electrically propelled car can be designed to use it.

Part 2 of this article was originally prepared and submitted along with Part 1 last year. The writer found it necessary to revise it, which indicates the rapid progress in the field.

Investigating the information required to prepare the sketch of the "Magnetohydrodynamic" (MHD) converter and its accompanying notes disclosed a weakness in the design. This was its low voltage. The laboratory devoloping the device managed to increase the current by "seeding" the hot ionized gases with powdered potassium or cesium to increase conductivity so that a respectable power output could be produced. At the present state of development, a multiplicity of such devices (series connected) would however be required to provide voltages high enough to be useful for the electric propulsion of road vehicles.

Each of the direct conversion devices shown in Part 1 represents merely a basic cell. A multiplicity or a battery of them would be needed to produce useful voltages. The MHD converter, however, may be too complex and costly if multiple units are necessary.

The author attempted a redesign of the basic MHD cell to incorporate a multiplicity, or battery of cells, within a single unit. It is believed that such a redesign will demonstrate that any of the basic laboratory (cell) converters may be improved to meet the requirements of a specific application. The redesigned MHD Converter, called a "Cascade Voltage Multiplier" or battery of individual cells within a single structure, is shown as Figures 2A and 2B, herewith. It was successfully tested in the author's home laboratory (basement) using a moving metallic solid to simulate the conductive ionized gas or liquid.

Just recently, the first practical alternating current direct conversion device was announced by a leading research laboratory. While insufficient data are on hand to prepare a sketch

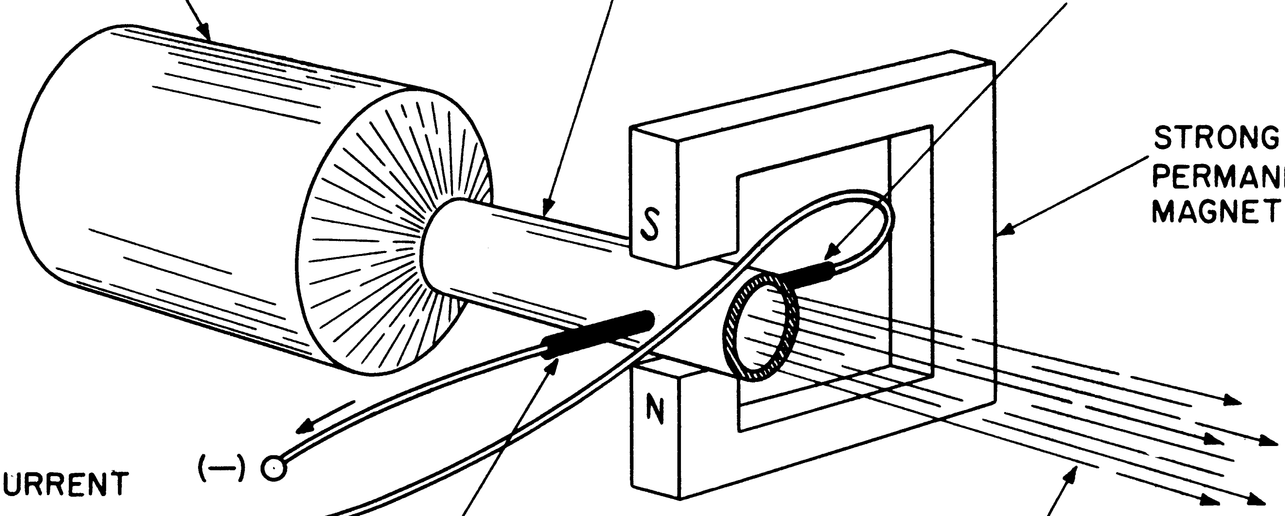

FIGURE I

ONE FORM OF HOT IONIZED GAS CONVERTER

CALLED "MAGNETOHYDRODYNAMIC" (MHD) POWER GENERATION

(OPEN-CYCLE SYSTEM SHOWN)

THIS IS CONSIDERED A "PASSIVE" SYSTEM, SINCE THERE ARE NO MECHANICAL MOVING PARTS WITHIN THE GENERATOR, THUS PROMISING HIGH RELIABILITY.

THIS "MHD" TYPE OF "BLACK BOX" SOURCE OF D.C. ELECTRICITY COULD BE USED TO PROVIDE ADDITIONAL ELECTRICAL POWER FOR BRIEF PERIODS OF "PANIC" ACCELERATION TO HIGH SPEEDS, OR EMERGENCY ELECTRODYNAMIC BRAKING, IF THE "VOLTAGE-DOUBLER" SYSTEM IS NOT USED (SEE TEXT, PAGE 77), FOR THE ELECTRICALLY PROPELLED "'ULTIMATE' WHEELED CONVEYANCE."

NOTES

1. The rocket, jet motor, nuclear, or other source of hot ionized gas or air heats it to about 5000 degrees (F), considered a "plasma" temperature. The high temperature gas or air becomes ionized or conductive at this plasma temperature and is directed through the permanent magnet field by the insulated hollow tube of quartz or ceramic material.
2. As the ionized gas or air passes through the magnetic field, its conductive molecules cut the magnetic lines of force and generate DC electricity just as the conductive copper wires in a generator do, under similar conditions.
3. The carbon (conductive) electrodes, which protrude through the insulating tube into the gas stream make electrical contact with the ionized (conducting) gas, through which the current, produced by the motion of the gas through the magnetic field, is collected and fed through wires to the point where it may be used.
4. The "open-cycle" system shown is good for only a few seconds of high electrical output when a solid propellent rocket source is used. Laboratory models have developed one KW of power for five seconds in initial tests. A closed-circuit system may be designed for recirculation of the hot ionized gas, in which case no noxious fumes will be emitted and a nuclear, instead of a chemical fuel may be used. Should such closed circuit system be developed a new type of nuclear fueled "Black Box", using "MHD" conversion methods would be available for the "Ultimate wheeled conveyance" and other uses.

at this time, it is known that the device is thermal and that the AC frequency is 100 kc per second. While this is not exactly what the power companies have been eagerly awaiting, it is the first step toward a passive AC direct conversion device. Should future developments provide 60 cycle AC, the converter would be useful in existing distribution networks. In any case direct conversion devices have been inherently more efficient than the present rotating machinery. Since they are passive (contain no mechanical moving parts) their maintenance should be less costly and their reliablity should be greater.

In view of such rapid strides in the development of direct conversion power sources and the continually expanding interest in their application, it would appear that we live on the brink of a new era - an era filled with great promises in the fields of power, transportation and communications.

Our own communication field we expect will feel the impact of such developments. Present applications include solar energy conversion to DC power for use in remote telephone areas. Recently a central office "common battery" of 28 volts for use by the Army Signal Corps was developed. It uses a battery of the "fuel cell" type of direct conversion devices. The writer was advised that the American Locomotive Company had developed a nuclear converter for, for instance, supplying power at isolated DEW line installations to which the shipment of fuel oil is difficult. Only a slight stretch of the imagination is required to place such a compact nuclear power package in an existing locomotive, in place of the diesel engine and generator.

New applications for direct conversion devices continually suggest themselves. Remote hill-top microwave radio relay sites now powered by diesel generators would appear to invite the application of direct conversion devices. Many others in the communication field await study and evaluation. It is conceivable, for instance, that even central office batteries in large cities such as ours could be replaced by large direct conversion devices which would obviate the need for costly motor generator sets and for standby diesel alternators.

Having examined the latest developments in direct conversion power sources, let us now go back for a bit to the beginnings of electric propulsion, before we attempt a further evaluation of Walter Baker's 1902 to 1905 electric racing cars.

In Part 1 of this article Daniel Davis was said to have been the first to recognize, back in 1842, that an electric motor is the simple converse of a generator. He was, of course, referring to the rotating armature machine with a commutator and fixed field magnets. The present series type direct current motor was originally designed as a generator and in that lies its weakness as a high speed device. While the motor is converting the electricity furnished by the storage battery or other source into mechanical power at the shaft of the revolving armature, the armature itself acts as an electrical generator as its coils revolve in the magnetic flux of the fields. This self-generated electromotive force is opposite in direction to the storage battery electromotive force being provided at the motor terminals and is called, logically enough, the "back electromotive force" or "back EMF" of the motor. At high rotating speeds this back EMF opposes and diminishes the EMF provided at the

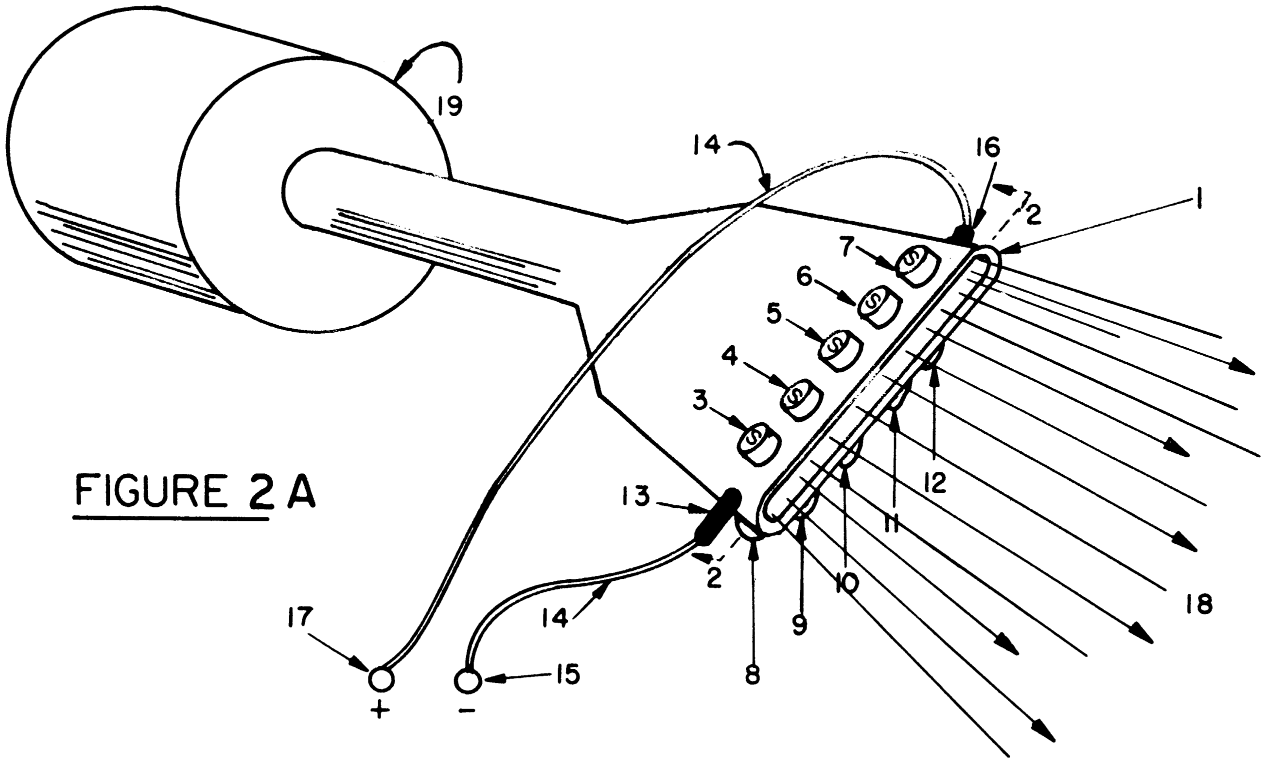

FIGURE 2 A

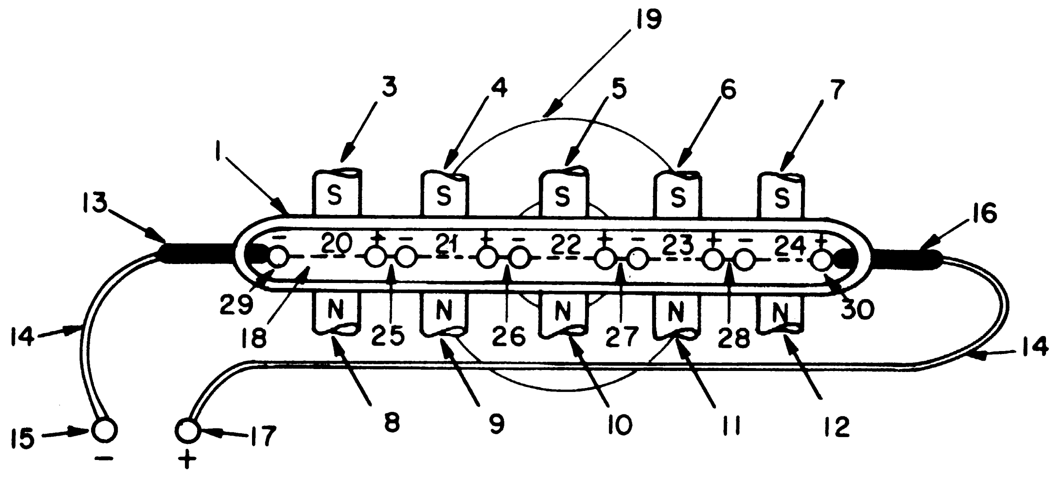

FIGURE 2B

(SECTION 2-2 OF FIGURE 2 A)

MAGNETOHYDRODYNAMIC (MHD) IONIZED GAS (OR LIQUID) CONVERTER ARRANGED AS A CASCADE VOLTAGE MULTIPLIER OR BATTERY OF INDIVIDUAL CELLS WITHIN A SINGLE TUBE.

MAGNETOHYDRODYNAMIC (MHD) IONIZED GAS (OR LIQUID) CONVERTER ARRANGED AS A CASCADE VOLTAGE MULTIPLIER, OR BATTERY OF INDIVIDUAL CELLS WITHIN A SINGLE TUBE

1 - Hollow tube of molded quartz, ceramic or other insulating material directing ionized gas or liquid flow through magnetic fields.

3, 4, 5, 6, 7 - South poles of magnets.

8, 9, 10, 11, 12 - North poles of magnets.

13 - Conducting carbon or metallic cathode protruding through tube to contact ionized gas (or liquid). Negative Collector.

14 - Conducting wire or bus.

15 - Negative terminal.

16 - Conducting carbon or metallic anode protruding through tube to contact ionized gas (or liquid). Positive Collector.

17 - Positive terminal.

18 - Ionized gas (or liquid) advancing toward observer, or in direction of arrows, through tube.

19 - Hot ionized gas (or liquid) source.

20, 21, 22, 23, 24 - Conductive ribbons or bands of ionized gas (or liquid), each generating a Negative (-) DC potential on left and a Positive (+) on right, as it passes toward observer in its own localized magnetic field.

25, 26, 27, 28 - Conductive, but non-generating, bands of ionized gas (or liquid), passing through gaps between adjacent magnet fields, while advancing toward observer, and electrically connecting Positive (+) end of generating band on left with Negative (-) end of generating band on right, to provide conductivity for series (voltage additive) current flow across all generating bands from 29 to 30.

29 - Contact between left, or negative (-) end of series connected generating bands of ionized (or liquid) and negative brush (13).

30 - Contact between right or Positive (+) end of series connected generating bands of ionized gas (or liquid) and positive brush (16).

motor terminals to the point where the motor torque (twisting effect) and mechanical power output are reduced almost to the vanishing point.

The back EMF is generated almost in direct proportion to the speed of revolution of the motor armature. The higher the speed of the motor, or of the vehicle which it is propelling, the less effective the available battery EMF is in providing power at the wheels. Then too, at the higher speeds where the power is "pinched off" by increasingly greater back EMF, the vehicle needs more power to overcome air resistance. Consequently, vehicular speed is severely limited whenever an electric traction motor is used for propulsion.

There is a sunny side to this phenomenon of the motor also acting as a generator. The back EMF, which limits top speed so severely, also provides many of the desirable features for which the electric drive is noted. While starting, accelerating and climbing hills, the lower rotating speed of the motor armature generates little or no back EMF, so practically the full effect of the available source of electrical power is used for high torque and high power output at the motor shaft. This characteristic of the series type electric traction motor provides up to five times the normal running torque while starting, accelerating or climbing hills. The effect is similar to that which would be obtained with an internal combustion engine if gears were shifted to "low" in order to provide a five to one mechanical torque multiplication for starting. One of the advantages of the electric traction motor is that it does not need a gear shift for starting, accelerating or climbing hills. The motor is always connected to the wheels with a fixed gear ratio, while speed is controlled electrically up to a top speed of about 20 mph, at which point the back EMF generated prevents a further increase.

Overgearing an electric vehicle, in an attempt to provide design top speed of more than 20 mph before the back EMF limits the speed, merely reduces available torque for starting, accelerating or climbing grades. Under certain

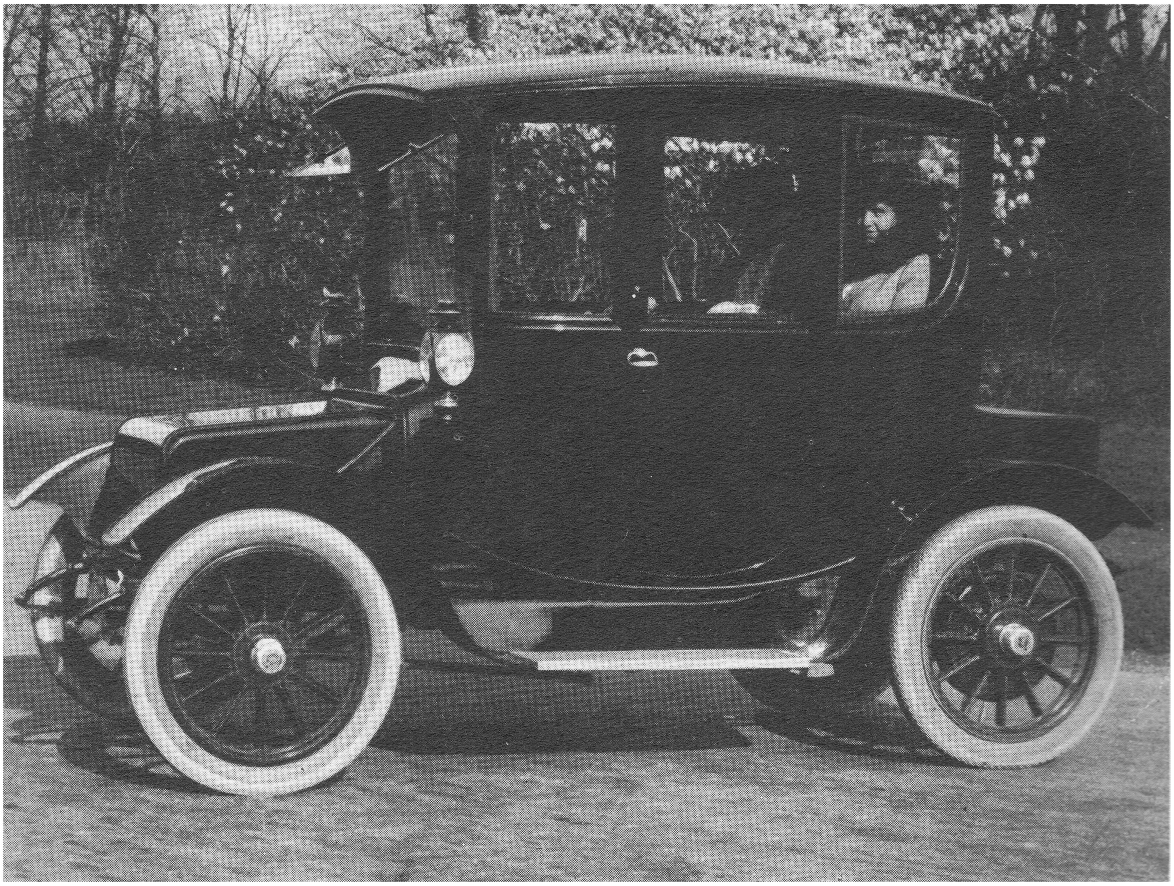

FIGURE 3
BAKER ELECTRIC COUPE
(SPEED 20 MILES AN HOUR - 80 TO 100 MILE RANGE)

conditions this has been done, but the longer accelerating periods result in excessive battery drains and a shortened range. Further, the over-geared vehicle many not be able to start on a steep grade.

Vehicles, like diesel electric locomotives, operating on steel rails may be geared for design top speeds of 65 mph or even higher, for the rolling friction on rails is only about one fifth of that of rubber tires on a road. Then too, in railroad practice, grades are usually limited to less than two per cent and the play in railroad couplings between cars allows the locomotive to start one car at a time, thus reducing torque requirements.

The problem is considerably greater and more limiting to speed in the electric road vehicle. With a speed torque range of about five to one (approximately the same as the electric traction motor used on the modern diesel electric locomotive) the road vehicle motor must be geared to start with considerably higher static resistance due to the deflection of the tires and roughness of the road. It must also be geared to climb a 7.6 per cent grade, said to be the "average of maximum grades in our cities". In each case, the five to one speed torque range of the motor and the back EMF speed limitation will dictate a gear ratio that will limit the top speed to about 20 mph, or slightly over.

Many individuals quickly recognized that the limiting factor in obtaining higher road speeds for electric vehicles was the generation of back EMF. In the early days it was reasoned that a reduction of field strength in the motor would reduce the tendency to generate back EMF, if it could be achieved while maintaining a high impressed voltage and current on the armature. Of course, weakening the field flux actually does reduce the number and strength of the lines of force cut by the coils of the rotating armature, thus reducing the generation of back EMF. At low speeds a strong field is required for high torque, so the field weakening process must be inserted only at high speeds and to a limited extent so that the armature operation as a motor will not be seriously affected.

Edison extended the speed range of traction motors by shunting or bridging the fields with the starting resistance on the high speed step of the controller. Baker used "field switching" - i.e., he arranged his fields in series for starting and in parallel for high speed running (see Figure 9) for his production vehicles. Steinmetz used "field cell", a single storage cell connected across the series field to control the field flux and reduce it at high speeds. Others used variable intrusion of the field coil cores or variable reluctance of the fields effected by mechanical or electrical means.

In each case, however, all that could be obtained by these methods of controlling the field flux to reduce back EMF was a 15 or 20 per cent increase in top speed. In effect, an additional high speed tap on the controller could be provided to increase vehicular speed from 20 mph to 24 or 25 mph. Fringe benefits accrued, however. Baker's method widened the speed torque range to well over five to one when fields were switched. Steinmetz's method provided regenerative (electric) braking without the requirement of reversing the fields when needed. Only Edison's and Baker's methods are in use today, sometimes in combination. A five mph increase in design top speed to 25 mph is, however, far from what is needed on today's high speed highways. It is not near Baker's 104 mph in the midget "Torpedo Kid" and the 120 mph average speed of the monster "Torpedo", achieved years ago.

Baker achieved these startling speeds when other electric racers were completely outclassed because they used conventional methods. Even the gay young blades of the turn of the century, with "souped-up" electric coupes running with "saturated" motors were unable to exceed 28 or at times 32 mph on the level. Since these early forerunners of the sports car enthusiasts never knew how Baker did it, they turned to the internal combustion engine for higher speeds.

Baker, in a road race in 1902 over city streets, managed to propel his juggernaut, the electric powered "Torpedo", at 80 mph to lead a field of the world's fastest steam and gasoline cars. This race, unfortunately, ended in a crash fatal to two drivers, but both Baker and his electrician came out of it uninjured. The incident convinced Baker that a smaller racer would be safer for all, and this led to his midget "Torpedo Kid". All of Baker's subsequent speed trials, including the 120 mph average record for ten miles, were made on tracks, beaches or blocked off public highways with spectators at a safe distance.

Baker's secret, his key to high speed electric car performance, used only in his racers, was simple and bold. He merely cancelled the speed killing back EMF of his series traction motor by providing an equal battery EMF to overpower it, and then added extra voltage to meet the torque and his great speed requirements. He had an eighty volt battery in his "Torpedo", but used a twenty volt motor. He had a twenty-four volt battery in the midget "Torpedo Kid" to feed a six volt motor. In each case the gearing was for a design top speed of about 30 mph. The vehicle started at motor name plate voltage. As back EMF pinched off the torque when the motor gained speed, he cut in additional cells of battery to cancel it and then cut in more cells for higher horsepower. Of course the motor might have been destroyed by the extreme heat developed, but the battery would exhaust before this occured.

Baker's electric racers, each of which held the unlimited world's record in turn, did not have to start on a grade, for they were racing cars, pure and simple, designed to demonstrate the top speed supremacy of electric cars over contemporary gasoline vehicles. In other words they were designed to advertise the Baker electric production car and not as practical day in and day out utility vehicles. They consequently could be geared for high speeds and to take the penalties of being difficult to start, of excessive battery drain in starting and of short range. There is some evidence in the record that the cars were overgeared, for reference is made to the difficulty in starting in the sands in the vicinity of Daytona Beach, when they made their attempts to extablish a new world's record for speed. After reaching top speed, they merely had to maintain this speed for a measured mile, at the end of which, no doubt, the battery was exhausted. If more than one attempt were necessary, the electricians would probably replace the storage battery with a freshly charged one. This was true when the Baker "Torpedo" achieved a sustained speed of 120 mph for 10 miles. This only required that the battery produce a maximum output for five minutes, plus the accelerating time (perhaps another five minutes) for a total of ten minutes.

Baker merely traded range for speed in his racers, and traded speed for range in his 20 mph production electric cars. However, his early discovery of how to overcome the speed limiting effects of back EMF in a tractive type electric prime mover by providing higher voltages at speeds where it becomes significant may survive in modern design. This technique has already been "rediscovered" by at least three independent researchers. It will probably be required for brief periods while passing, at least until an electric motor without back EMF or with some control of its generation of back EMF is invented.

Meanwhile, to confirm some of Baker's racing car techniques and further to evaluate the findings of the 1953 high speed electric car (Figure 5 of Part 1 of this article), the author decided to design and fabricate a small electric racing car that approached as nearly as possible the weight and power characteristics of Baker's 1903 design, the "Torpedo Kid", and that employed modern road racer techniques for safety.

In 1958, the completely handmade electric racing car was completed. It weighed 420 pounds as compared to the 450 pounds of Baker's car. With its driver each car weighed 600 pounds, ready for the road. The electric series traction motor of this new racer consisted of a 7-horsepower, 24-volt aircraft starting motor, originally designed to crank a 625 horsepower aircraft radial engine at 300 amperes drain. It weighed 27 pounds as modified to provide reverse and field switching (speed control) features, in accordance with Baker's usual design. By providing 30 volts (5 six-volt battery units) at 360 amperes, it would produce 11.2 horsepower at a tested 80 per cent efficiency. The additional motor horsepower was required, as it developed, for the new design was in chassis form with steamlining provided only to its underpart.

This new machine was designed as a 1/3 scale model of the Maserati road racer that then held the world's championship. The first project was to determine the horsepower required by Baker's "Torpedo Kid" for speeds in excess of 100 mph and the range capabilities of the racer.

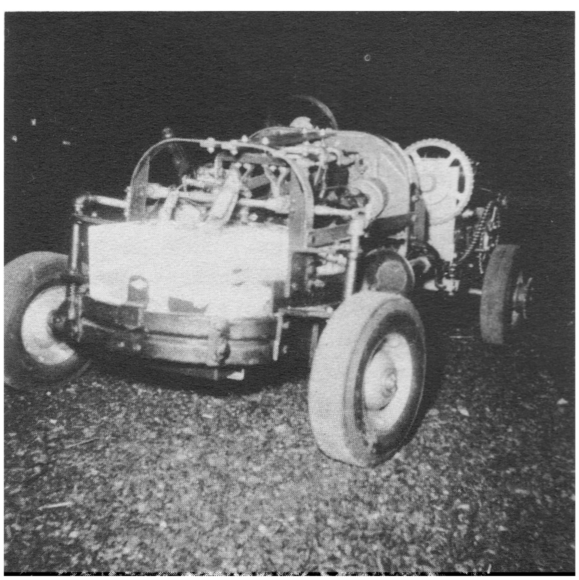

FIGURE 4
1958 MIDGET ELECTRIC RACER - ONE THIRD SCALE OF MASERATI WORLD CHAMPION ROAD RACER DESIGNED TO TEST BAKER'S ELECTRIC RACING CAR CONCEPTS.
(DESIGN SPEED OVER 100 M.P.H.)

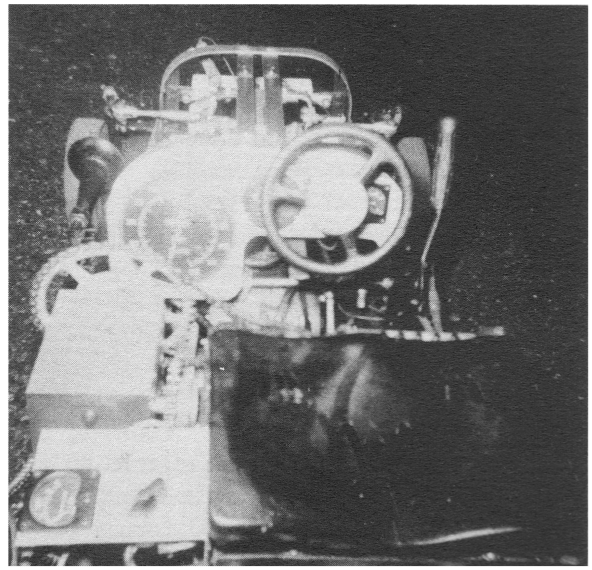

FIGURE 5
DASHBOARD VIEW OF 1958 MIDGET ELECTRIC RACER
(NOTE: 120 MPH SPEEDOMETER, 300 AMPERE, & 30 VOLT METERS, RIGHT HAND DRIVE, HAND BRAKE AND PUSHBUTTON CONTROLLER)

The test runs on the road confirmed the research data findings. The vehicle used the brute force method of starting, creating severe drains on the 130-ampere hour batteries. Drains well in excess of the 300-ampere range of the dashboard ammeter were normal for starting on the level and for accelerating, even when the battery was commutated for lower voltages and the armature fields were switched for series operation. Initial test runs of up to 55 mph were made on a 1200-foot stretch. All U turns were, of necessity, made at relatively high speeds, for slow speed maneuvering and the use of the 300-ampere rated reversing switch resulted in heat damage to switch and cable and visible bubbling of the storage battery electrolyte. Fortunately, the cornering characteristics of the car were remarkably good - even to a former road racer and sports car enthusiast - for it was necessary to minimize current drain by making a "U" turn, at the end of a 20-foot wide road, at 25 or more mph. The main problem on these abrupt turns was to "stay in the saddle" but the small car did not slide or lean and there was no tire squeal.

Repeated road tests with a minimum of starts revealed that about five minutes would elapse before the battery was exhausted. On one hectic day a maximum range per charge of just barely four miles was achieved (at 48 mph average speed over about a quarter mile stretch of road, including "turn arounds"). The new 43-pound six-volt battery units, five of which were used on these tests, were rated at 5.5 minutes at 300 amperes drain, so the five-minute life must have resulted in an average drain well in excess of 300 amperes.

All of this proved that while the range was too low for any practical purpose, the 1903 Baker "Torpedo Kid" really had been capable of making successful speed runs over a one-mile stretch of beach or track. One final test of that 1958 car on a 30 per cent grade, an attempt to start, was conclusive proof of the impracticability of a high speed electric with overgearing and a motor "captive" to the drive train. The car simply would not start on the grade and all electrical cables and connections overheated dangerously.

Needless to say, on a test stand run with a controlled load on the spring balance countershaft brake, the car was able to show just over 100 mph on its speedometer, at just over eleven horsepower. With a calculated coefficient of air resistance of .0012 (somewhat inferior to the steamlining of the Baker midget racer) the car would, without doubt, achieve the 100 mph design speed on the road. The stand test was safer than risking life and limb to prove the point, nor was such proof essential.

Having proved that high speeds were possible by the use of overgearing and the provision of higher voltages to overcome back EMF, at the penalty of incurring severe battery drains and with the inability to start on steep grades, the next step was to confirm a proposed solution to the weaknesses of the design.

While Baker had solved the problem of back EMF for his racers by a "voltage doubling" technique, the author's 1953 method was to limit back EMF in the motor by preventing the motor from exceeding its design speed, even at high vehicle speeds. This involved the use of two (or more) gear ratios between the motor and the wheels through the provision of a gear shift. The "start" or "low range" ratio inserted mechanical torque multiplication between the motor and the wheels, providing for low current drain when starting on steep grades and while accelerating. When speeds approaching 20 mph were reached and the back EMF started to limit the vehicle to this speed, the gear shift lever was moved to the "drive" or "high range" position, which slowed the motor, reduced back EMF and increased the torque (and horsepower) which allowed the vehicle to accelerate to beyond 40 mph before back EMF again limited its speed. At this point the design voltage of 24 volts was increased to 36 in order to provide further acceleration to over 50mph. This latter involved partial use of Baker's technique of using higher voltages to cancel back EMF.

It appears proper to say that the author claims the gear shift or mechanical torque conversion as his contribution to high speed electric cars. This small car was to be used to test it in a continuously variable (as opposed to step-shift) form.

A patented working model of an electro-mechanical torque converter was mounted on the chassis. (Part of the plan in constructing the midget electric racer was to test the torque converter, originally designed for a gasoline powered car.) Figure 4 shows the 1958 electric midget with torque converter installed. Figure 5 shows a view of the dashboard with the push-button motor controls to the right, just in front of the driver's seat and the control knob for gear ratio control to the left of the driver, just below the meter which indicates the ratio in use, on a continuously variable basis.

In preparation for road tests with the new speed-torque converter in the drive train, the overall design gear ratio was changed so that design speed was 120 mph. The car was thus even more overgeared, for the new weight including the torque converter but without driver was well over 500 pounds and it was necessary to increase the design horsepower at 100 mph to 12 horsepower. This one horsepower increase was achieved by loading the motor at 100 mph to over the design load by further overgearing. (The series motor automatically compensates for this additional loading by increasing the current drain.)

Thus equipped and after some preliminary torque converter trouble, the car soon proved that it could start on the traditional 30 per cent grade without excessive drain, following which it was able to accelerate like a sports car to 65 mph with reasonable drains. "All out" acceleration tests with the torque conversion operating were finally made at full output. The car would "jump start" like a racing motorcycle, easily achieving wheel spin on dry pavement, and on several occasions it even lifted both front wheels clear in accelerating.

In a carefully prepared test on a 500-foot straight stretch of black-top road, the car was accelerated to 65 mph and then braked to a stop within the measured 500 feet. Since the brake skid marks showed 150 feet of braking and there were no wheel spin "rubber burning" marks on the road at peak speed of 65 mph, it was possible to compute the acceleration from this test. It worked out to better than 0 to 60 mph in eight seconds - definitely sports car performance. This was done, it should be noted, with the torque converter because of mechanical difficulties working only over a portion of its range.

This experiment proved the further point that, with torque conversion or gear shift, a high speed electric car was practical and economical, for with torque conversion the range of this car was extended from four miles on a charge, to a tested 30 miles, at average short run speeds of 30 to 45 mph.

This ends **the** saga of the midget electric racer that was constructed to evaluate Walter Baker's original design of 55 years before. From this 1958 version much had been confirmed and much had been learned. The most significant finding was that maximum benefits for a modern high speed electric car require the use of both Baker's voltage doubling technique and the author's gear shift or torque converter technique.

As the result of an even more recent (1959) venture in design and engineering, the author believes he now has the prototype of the car of the future in his garage. It was completed late in July, 1959, and initial road tests were successfully completed by August 1, 1959.

In this 1959 model the body type picked for conversion to electric drive was that of an "economy" car, as differentiated from "utility" cars, such as the Renault and Volkswagen. A Baker-Raulang electric motor of a type similar to that used in Baker's big "Torpedo" racing car was obtained for its power plant. Although this motor is a mere 1.78 horsepower at 21 volts and 7.2 horsepower at 42 volts, Baker continually used one

FIGURE 6

1959 PROTOTYPE OF THE 'ULTIMATE' WHEELED CONVEYANCE

TOP SPEED - 80 MPH ("PANIC SPEED")
SUPER HIGHWAY SPEED - 60 MPH (SHORT RANGE)
STATE HIGHWAY SPEED 40-50 MPH (DESIGN SPEED)
RANGE - 80 TO 100 MILES AT LOWER SPEEDS

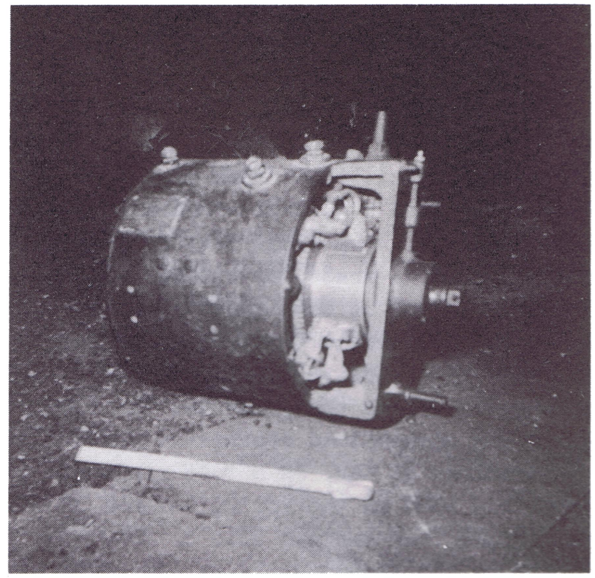

FIGURE 7

THE BAKER-RAULANG SERIES TRACTION (ELECTRIC) MOTOR USED IN 1959 PROTOTYPE (FIGURE 6)
WALTER BAKER'S 120 MPH "TORPEDO" ELECTRIC RACER USED THIS TYPE OF MOTOR. (THE RULE IS ONE FOOT LONG.)

like it for brief periods, for an output of from 28.8 to over 45 shaft horsepower for his record runs in the big "Torpedo" racer. The car is also equipped with a speed-torque converter, a voltage doubler for emergency use and arranged for the eventual use of a black box power source. Although equipped with light weight lead-acid storage batteries for performance tests, the 1959 prototype started road tests with the following target objectives:

1. Super highway speed of 60 mph for short range use only.

2. Design voltage cruising speed of 40 to 50 mph for state highway operation.

3. Maximum range, at the lower speeds of 80 to 100 miles on a charge, while using storage batteries. (This limitation will be removed when black box power sources are available.)

4. The ability to start on and climb any grade that might be encountered in the U.S.A. A 40 per cent grade was viewed as the objective.

5. The ability to accelerate in a manner comparable to the best American full-sized production cars.

6. Emergency or "panic" top speed of 80 mph, for momentary use only.

Initial road tests in August 1959 confirmed the design cruising speed, the ability to start on steep grades and the acceleration performance. Final evaluation, now in progress, has proven it capable of the 60 mph superhighway speed. Range

BAKER R & L TYPE # 2048 SERIES TRACTION MOTOR TESTED AT 21 VOLTS – (24 VOLT BATTERY AT 1.75 VOLTS PER CELL)

MOTOR HAS CONTINUOUS RATING ON 24 VOLT LEAD ACID BATTERY AT 80 AMPERES (DESIGN CURRENT)
(21 V. LOCK – TEST, OR STARTING CURRENT SURGE 520 AMPS. WITH FIELDS SERIES, AT 180 LBS/FT. TORQUE)

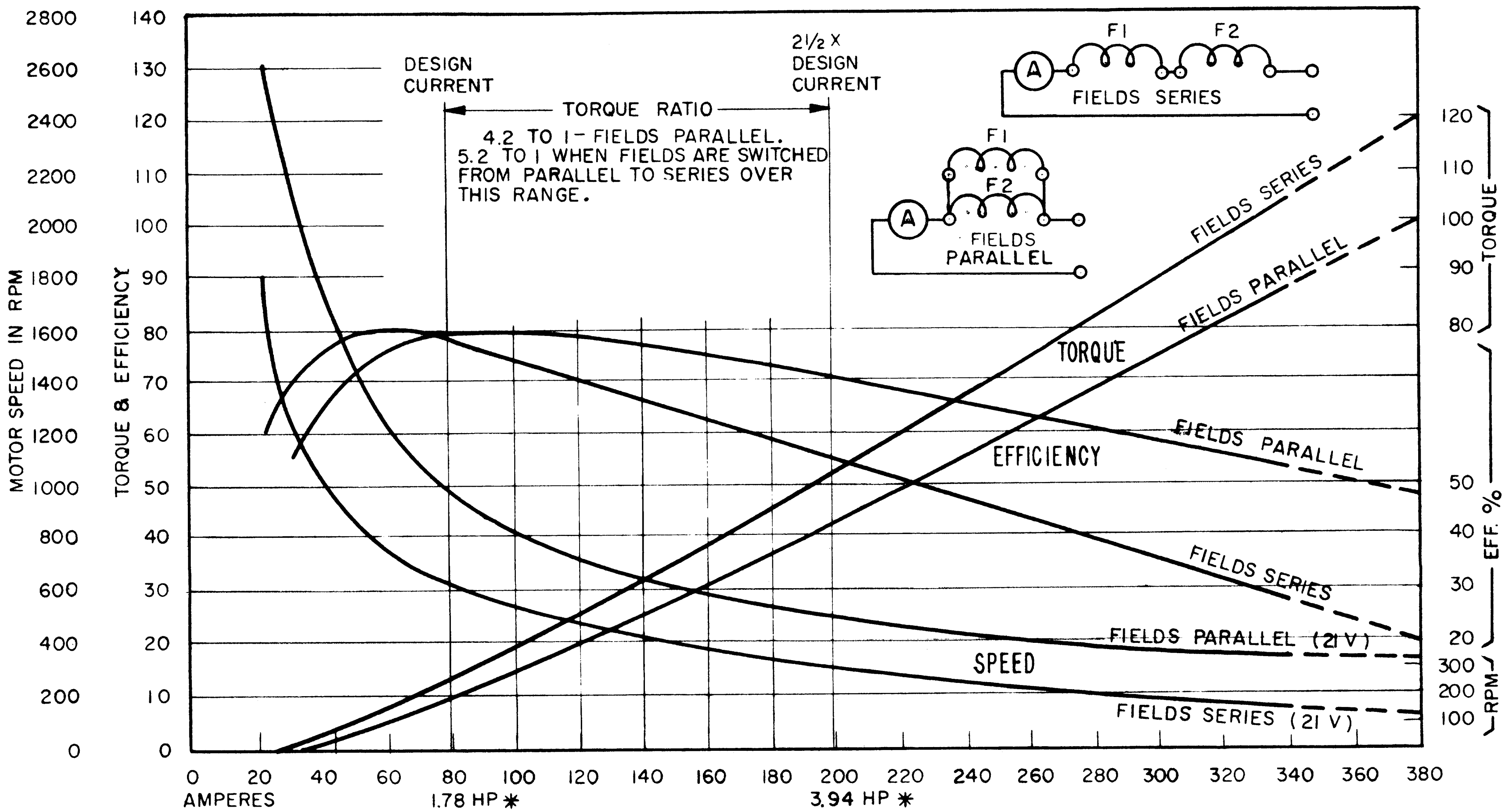

FIG. 8

A GRAPH OF CHARACTERISTICS OF THE BAKER TRACTION MOTOR SHOWN IN FIG. 7. THE TORQUE RATIO RANGE OF THIS MOTOR IS 5.2 TO 1 WHEN FIELDS ARE SWITCHED. IF THIS RATIO SHOULD BE TOO SMALL, THE STARTING CURRENT WOULD BE DEVASTATING TO THE BATTERY. FOR EXAMPLE, WITHOUT FIELD SWITCHING, THIS RANGE IS 4.2 TO 1 WHICH WOULD GIVE A 740 AMP. STARTING SURGE, INSTEAD OF 520 AMPS.

AT 20 MPH DESIGN SPEED AND MOTOR CAPTIVE TO WHEELS AT 1000 RPM, MINIMUM DWELL AT STARTING SURGE AND ACCELERATING CURRENT LEVELS WOULD EXIST. OVERGEARING FOR HIGHER DESIGN SPEED WOULD INCREASE THIS DWELL AND THE PERIOD OF HIGH DRAINS, TO THE DETRIMENT OF RANGE.

* SEE TEXT

tests are now being conducted, but the final results have not been evaluated at all speeds. All that remains to be proved is the 80 mph "panic" speed. (Tests at 60 mph indicated that there was much in reserve.) There is no reason to doubt that, at 63 to 72 volts, the motor will produce the 28 to 33 mph that will be required to reach 80 mph. All in all, the writer is confident that his 1959 test model has effectively proven its practicability and its capability.

A word about the maintenance requirements of an electric car appears to be in order. It will eliminate many of the maintenance problems associated with the gasoline car. The electric will have a mere 20 or so moving parts as against the many more in its gasoline powered counterpart. When a lead-acid battery is used, distilled water will, of course, be required on a periodic basis. With silver-zinc, silver-cadmium or nickel-cadmium cells, however, this need would practically disappear, for these cells may be sealed. A periodic tightening or treating (with vasoline) of the cell connectors may be required. Other than this, nothing else seems necessary, except for controller adjustment or switch maintenance on a long-term periodic basis. New brushes for the motor at 20 to 40 thousand miles might cost $10 or, installed, $20.

The operating costs of the electric will be much lower than that of the gasoline type. Not counting oil changes (oil is not used in the electrics), the gasoline car does well to operate at two cents a mile (fuel cost alone based on about 15 miles per gallon). All three commercial electric cars ready for production claim a fuel cost (through the electric meter) of less than 1/2 cent a mile which makes them more economical than even the European midget gasoline cars. Their fuel is roughly equivalent in cost to obtaining 60 miles on a gallon of regular gasoline. This is due to the much higher efficiency of the electric traction motor, which at design speed is usually over 80 per cent. Gasoline engine efficiency, even with the best design, is usually about 10 per cent.

The first appearance of American cars caused proponents of the horse to shout, "Get a horse!" in derision. At sea, when the era of wooden ships and iron men was nearing an end, the sailors of the wooden ships used to shout, "Smudge pot!" at those on the smoke-belching steamships. And the shouts turned to praise - - -.

The writer is now anticipating the early delivery of a commercially produced electric car. It may not fully meet all his expectations and he may be tempted to tinker with it and to modify it somewhat, for after all, it will not entirely be the "ultimate" wheeled conveyance. He is sure, however, that it will be an economical and clean car, and one that will give him a great deal of pleasure.

- C.R. Whiting
Manhattan Engineering

BIBLIOGRAPHY:

Machine Design - Maleev & Hartman - 1954 (Int. Textbook Co.)

Spiral & Worm Gearing-Eric Oberg - 1917

Connecting & Testing Direct Current Machines - Annett & Roe - 1937

The Electric Motor Truck - Edward E. LaSchum - 1924 (Society of Automotive Engineers)

Storage Batteries - Arendt - 1928 (RCA Institute)

Exide Topics - Summer Edition - 1959 - Article titled "Renaissance in Electrics" - The Electric Storage Battery Company, Phila.

Technical Brochure on "Silcad" Storage Batteries (Silver-Cadmium) -Yardney Electric Corp., New York - 1959

The First Hundred Years - R. Thomas Willson - The Baker-Raulang Co., Cleveland - 1953

Engineering News - May 1959 - (Radio-Isotope Fueled Generator) - Miniature Precision Bearings Co., Keene, N.H.

New Power Sources for Space Age Electronics - David Linden and Arthur F. Daniel - Electronics, March 20, 1959 Issue

General Engineering Bulletin - Spring & Summer Issue - 1954 - (Article on Electric Car - "The Reluctant Dragonette") - New York Telephone Co., 140 West St., N.Y.C.

Graph - Speed, Torque & Efficiency Curves on Baker R & L (Electric Traction) Motor #2048 - The Baker Raulang Co., Cleveland.

Filth in the Air - Ruth & Edward Brecher - Redbook Magazine - April 1959 Issue

Electrical World - Issues of Feb. 18 & April 6, 1959 "Tel Electric Debuts in London", "Men Behind Electric Car Look to the Future" - McGraw Hill, N.Y.

Memorandum to N.Y. Tel. Co. Eng. Dept. proposing a field trial of Electrical Vehicles in Manhattan, by N.Y. Tel. Co. Plant Forces - C.R. Whiting May 27, 1959.

ADDENDUM :

For those who might wish to design and construct an electric car, for perhaps a child - or a grown-up child - some design data is given here. We shall attempt to limit our use of mathematics.

FIGURE 9

BRUCE WHITING ON 1952 MODEL "GO-KART" USING 1.6 HP GASOLINE ENGINE FROM A LAWN MOWER.

(WITH GASOLINE ENGINE SHOWN, TOP SPEED: 8 MPH - WHEN ELECTRICALLY PROPELLED, USING 1/3 H.P.: TOP SPEED: 15 MPH)

For speeds up to 15 mph, air resistance may be neglected although it begins to have a measurable effect on power requirements between 15 and 20 mph and becomes a dominant factor in design at around 45 mph. With good design, road resistance may safely be calculated at 30 pounds at the wheel rims per ton of weight. This is on a smooth concrete, macadam, or black-top road, and while using well-inflated pneumatic tires or the semi-pneumatic tires popular for junior midget cars.

If a "series" type or "compound" type motor is used (the shunt type will not do for traction use) and connected to the drive wheels with a chain or gear reduction appropriate to its name plate design speed, size of the wheels and road speed desired, then a 200 pound (including driver) child's electric car would require three pounds tractive effort at the wheel rims on level ground at 15 mph road speed. This would require an electric motor of a mere 1/8 horsepower, or about 1/4 horsepower if a "V" belt reduction were used, because of greater losses in transmission. In the first case, a standard automotive type six volt battery unit would last for about three hours and the car could travel for nearly 45 miles, at full speed. In the second case ("V" belt), the battery would last about an hour.

The same principles of design may be used for any sized electric car and for any reasonable design speed, within a series traction motor's speed-torque range. The formulas used are given below:

1. Tractive Effort Required on Level Smooth Highway
   (Basis: Road Resistance of 30 lbs. per ton)
   Te = Tractive effort at wheel rims (in pounds)
   Wv = Weight of vehicle in pounds, including driver and passengers.
   $$Te = \frac{Wv \times 3}{200}$$
   (See formula 6 for design speeds over 15 miles per hour.)
2. Ratio Between Wheels & Motor
   R = Overall ratio: Wheels to motor
   Pm = Revolutions per minute of prime mover (motor)
   C = Drive wheel circumference in feet
   c = Drive wheel circumference in inches
   S = Speed in miles per hour
   $$R = \frac{Pm \times C}{S \times 88} \qquad R = \frac{Pn \times c}{S \times 1056}$$
3. Motor Torque Required
   Pt = Prime mover (motor) torque required, in lbs./ ft.
   Te = Tractive effort required at wheel rims (from formula 1, above)
   Tr = Radius of drive wheels in feet
   R = Overall ratio: wheels to motor (from formula 2 above)
   Ed = Efficiency of drive train (use decimal)
   $$Pt = \frac{Te \times Tr}{R \times Ed}$$
4. Motor Horsepower Required
   HP = Motor Horsepower required
   T = Motor torque required (lbs./ft.)
   N = Motor revolutions per minute
   $$HP = \frac{T \times N}{5250}$$
   (Note: A 12 volt automotive starting motor can produce over 1/4 HP on 6 volts)
5. Motor Current Required
   I = Current in amperes
   V = Voltage of battery
   HP = Horsepower of motor (from Formula 4, above)
   E = Efficiency of motor (use decimal) (If not known, assume .60 for fractional HP to 2 HP, .80, over 2 HP)
   $$I = \frac{HP \times 746}{V \times E}$$
6. Air Resistance
   (Ra to be added to tractive effort Te in Formula 1, at speeds over 15 miles per hour)

Ra = Air resistance in pounds at wheel rims
V = Velocity (Speed) in miles per hour
A = Cross-section of projected frontal area of car, in square feet.
K = Coefficient of air resistance, due to streamlining. (The lower figure indicates better streamlining)
When unknown, use following for design:
K = 0.003 for trucks (or cars with exposed chassis)
K = 0.002 to 0.0025 for average U.S. Sedans *
K = 0.001 to 0.0015 for streamlined foreign economy or sports cars. (Utility cars use higher fiqure.)
* Note: Streamlining for beauty or styling is often not functional.

$$Ra = K \times A \times V^2$$

7. Quick Calculation of Horsepower Required for a Given Speed
(Based on missile, jet or rocket design rule: "At sea level one pound of thrust at 300 miles an hour equals one horsepower." This is known to be based on 20% slippage in the thrust stream-hence the following formula:)
HPe = Estimated horsepower required at prime mover.
Tt = Total tractive effort at wheel rims, in pounds, from formula 1 and 6 (Te + Ra).
Vr = Speed required of vehicle in mph. (Must be same speed "V" in formula 6 for which air resistance "Ra" was calculated).
Ed = Efficiency of drive train (use decimal).

$$HPe = \frac{Tt \times Vr}{375 \times Ed}$$

(Note: A single roller chain or gear reduction: Ed = .90; a double chain or gear reduction: Ed = .80. A single "V" belt reduction: Ed = .50

(Ed. Note 1. - We were caught in Steve's enthusiasm and, using his formulas, recently constructed our own electric from an abandoned perambulator, an electric clock motor, a handful of hairpins and some old flashlight batteries. We were stumped by the torque conversion unit, but finally made one from the parts of an old but sturdy egg beater. The results pleased us - so much so that we sold our old steamer, although we did retain our velocipede for rainy weather.)

(Ed. Note 2. - Someone recently sent us the lines by Dr. Ashley Montagu of Princeton, "We are inclined to pay too much attention to the fact-grubber and not enough to the man of imagination and ideas. - - - We need more rather than less speculation and conjecture - - -." The only trouble is that speculation runs to so many words - but at least, Steve, you stopped short of the "Ultimate" Flying Saucer, powered by a black box. At that, though, we envy you your curiosity, enthusiasm and new electric.)

(Ed. Note 3.- We don't exactly know why Steve gave us this item: The ambulance that carried President McKinley to the hospital after he was shot in 1901 was a silent electric.)

(Ed. Note 4.- The picture below shows the

1900 TAXICAB. Used in N. Y. City. Built by N. Y. Electric Vehicle Co.

editor in 1900 riding in one of New York's three hundred electric taxicabs - he gave up hansom cabs because they made him seasick. The doors of the taxi are invitingly open - but the 1900 damsels were a wary lot - or else they didn't like the idea of the driver peeking down at them through the hole in the roof. The driver, by the way, became a motorman for the BRT - Brooklyn Rapid Transit - and was given up for lost somewhere between Prospect Park and Coney Island. He left a wife and thirteen children, all having buck teeth.)

The desire of knowledge, like the thirst of riches, increases ever with the acquisition of it.

-Laurence Sterne

OLD WARHORSES seem to work longer, to thrive better and to receive more respect and honor in some fields more than in others - particularly, we think, in the fields of politics and music. (Did we mix a metaphor?) The other day Louis Biancolli, in the World-Telegram, wrote of the eighty-four-year-old Pierre Monteux, who had just conducted the Philadelphia Orchestra at Carnegie Hall - our memory of M. Monteux goes way back to the times of World War I, when he took over the Boston Symphony (because its previous conductor was dropped when he wouldn't include the Star-Spangled Banner in his wartime programs) - and he was a mature man then. Mr. Biancolli wrote, "Such concerts by artists like Pierre Monteux are evidence of the precious legacy of wisdom and depth that those of advanced years have to impart to younger generations. They are the links with a great tradition. They have as much to teach as we have to learn."

A.M. OR P.M. IN SUBURBIA - as an engineer trained to observe, we have been observing the wives who get their husbands to the 7:25 on time in the morning and who pick them up when the 5:49 rolls in, usually behind time, in the evening. The same wives, A.M. and P.M., but how different - we suspect that many of the husbands close their eyes when giving the A.M. kiss, but that most of them keep their eyes open when implanting the P.M. kiss. Maybe it's conspiracy by the wives - their A.M. looks make the husbands glad to get to work and their P.M. looks make the husbands, if not exactly eager, at least not too loath to come home with their earnings. (A disclaimer - to save our and sundry other necks - the foregoing, of course, does not apply to wives of telephone men.)

IT STARTED WITH "CONTACT", we think - this conversion of nouns to verbs which, it strikes us, is too often just plain laziness and not the dynamic vividness, inventiveness and freshness some condoners purport it to be. The other day we saw an announcement which stated that the so-and-so Company will now be "headquartered" at such-and-such City - and then heard on the radio that the United States is "hosting" the winter Olympics. We are already "missiled" by enough rules and exceptions without further "irregulariting" how we "language" our ideas. So many of us - including us - are tyros at diction - and still feel qualified to amend the dictionary.

FORMING POSSESSIVE SINGULARS of nouns always bothers us. We thought we'd be happy when we decided to take Professor Strunk's advice ("The Elements of Style" - MacMillan - you should have a copy, by the way), and would simply add a final "apostrophe s", whatever the final consonant - "Charles's friend", for instance. Good - but then we came to the exceptions - the possessives of ancient proper names ending in "es" or "is", where the final apostrophe is recommended. Elsewhere we wrote about Achilles, Patroclus and Paris. "Achilles' heel" and "Patroclus's story" sound pretty good, but not "Paris' story". Despite the exception, we think it would better be "Paris's story". (Who do we think we are?)

"I SHOULD HAVE TAKEN THAT JOB WITH THE TELEPHONE CO"