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THESIS  
USES OF ELECTRICITY IN  
GASOLENE AUTO CARS

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1915



This thesis was contributed by

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A Study  
of  
The Uses of Electricity in Automobiles

A Thesis Submitted to  
The Faculty of  
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By

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THESIS

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Outline of Proposed Thesis.

Title; The Use of Electricity in Gasoline Automobiles.

Object; To make a comprehensive study of the application of electricity to the modern gasoline vehicle.

Introduction; A brief review of the early history of the automobile together with a short outline of the first applications of electricity in that field.

Body; In so far as is possible the subject will be subdivided into (1) Ignition, (2) Lighting, (3) Starting, (4) Other applications. A study of the construction, the principles, and the operation of typical examples will be made.

## Introduction.

Ever since man has inhabited this globe he has been striving to devise means for the easy transportation from place to place of himself and his goods. Wheels have been the rolling device used for a period of more than four thousand years, oxen and horses being the original propelling power used by man as soon as he became sufficiently intelligent to find some force other than he himself could exert.

The spirit of invention and improvement among thinking men appears to have first sprung up in the fourteenth century as is shown by the prophetic words of Roger Bacon, a philosopher of that date:

"We will be able to construct machines which will propel ships with greater speed than a whole garrison of rowers, and which will need only one pilot to guide them, we will be able to propel carriages with incredible speed without the assistance of any animal and we will be able to make machines which, by means of wings, will enable us to fly in the air like birds."

The first authentic record of the application of a mechanical device for the propulsion of vehicles is in the sixteenth century when John Haustch brought out at Nuremburg, Holland, a spring propelled vehicle. Steam propelled vehicles appeared in a practical form in England in 1770 but attempts were made as early as the thirteenth century. Steam seems to have been the general favorite in this field until

the latter portion of the nineteenth century when the application of the internal combustion engine to this field first became anything more than an experiment.

The gasoline motor was first used for vehicle propulsion with success about 1888 but was proposed at an earlier date by Henier in France when in 1860 he took out patents for an explosive motor vehicle. Benz, in Germany, was one of the first to produce a successful motor wagon which was publicly exhibited in Munich, Germany, in 1891.

A host of experimenters in France, among whom may be named Serpollet, Pengot, Panhard, Havassor, Kreiger, De Dion, and Bouton as pioneers in this field, have contributed largely in perfecting the mechanism of the automobile and thereby giving it a distinctive reputation upon which American inventors have widened its mechanical and economical adaptation for vehicle construction and motive power. The Duryeas took up the experimental line in automobile motors in the United States, in 1886 and after five years of personal effort, they produced their first motor vehicle in 1891. Others, in this country, soon fell into the same line of experimental construction, so, that the beginning of the twentieth century found the motor car industry a thriving infant which has since grown to enormous proportions.

The earliest experimenters soon found that the use of hot tube ignition in internal combustion motors was hardly all that could be desired and the substitution of an

electric spark as a means of igniting the explosive mixture formed the first recorded use of electricity in a gasoline vehicle.

## IGNITION

There are two systems by which ignition of the explosive charge of a gas engine is accomplished electrically; viz., the make and break system and the jump spark system. For the large stationary gas engines and engines used for purposes which do not require close regulation and a delicate balance of reciprocating parts, the make and break ignition system is used by the manufacturers. It is the choice of the manufacturers because of its simplicity, and it is simple because it requires no spark coils, vibrators, condensers, etc., in the electrical circuit to get out of order. The circuit is unbroken except for the point where it is closed and opened at the required time.

However, such a system does not give close regulation and has a number of reciprocating parts. Close regulation is desirable in an automobile engine and the reciprocating parts would soon wear, giving the engine poorer regulation with more noise. One very undesirable feature, of the make and break system, is the corrosion of the contact points for making the spark and which are located inside the cylinder. Because of the great heat generated by the burning charge and that generated by the spark itself, the contact points become pitted and corroded so much that good contact is not always made each time desired which results in no spark at all, and not only lessens the total power delivered to the crank shaft, but also wastes the fuel. The objectionable features, inherent in such a system, are

eliminated, to a great degree, in the jump spark system which has stood the test and become standard for ignition in the automobile work of the present.

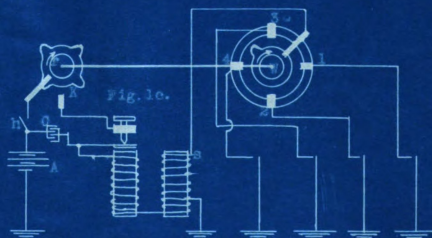
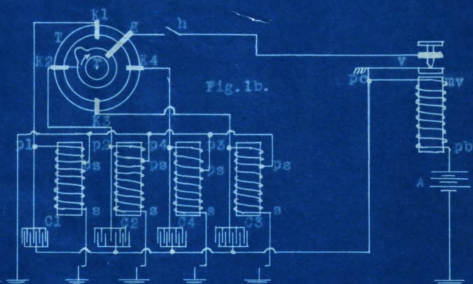
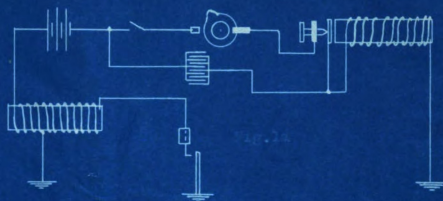
The jump spark system is a system by which the primary current from some source of electric current of low voltage is converted by an induction coil into a secondary current of sufficiently high tension to cause a spark to jump an air gap. Heavier insulation is required in this system, especially in the secondary circuit, because of its high tension, than is required in the make and break system.

The essential elements of a simple jump spark ignition system consists of: some source of Electromotive Force, ( a primary battery, a storage battery, or a generator); a switch for opening the primary circuit when not in use; a timer which will close the primary circuit at the proper instant that it is desired the explosion in the engine cylinder occur; a spark coil, consisting of two coils of wire inter-wound on an iron core, one coil of a few turns of wire and the other coil of many turns; a spark plug which is a device for conducting the high tension secondary current to the interior of the engine cylinder, and allowing the spark to jump across a small gap in the circuit at a certain point predetermined to be the most advantageous by the engine builders; and an interrupter, or vibrator, for making and breaking the primary circuit more rapidly than the timer does, which produces a shower of sparks at the spark plug instead of a single spark. The last essential,

the interrupter, is not needed where alternating primary current is used, as, for instance, the current from a magneto. Many manufacturers, too, claim that a shower of sparks is not needed to ignite the gas in an engine cylinder, that one hot spark is all that is needed and is desirable in that it saves current where batteries are used as a source of current. Hence, even on some systems using direct current, the vibrator is omitted, one spark occurring at the instant the primary circuit is closed by the timer.

Considering only direct current in the primary, the course of the current is from the positive pole of the battery or generator to the interrupter, from the interrupter to the primary winding of the spark coil, from the primary winding of the spark coil to the timer, from the timer to the engine frame and back to the negative pole of the battery, or generator. The interrupter, working on the same principle as the electric buzzer, causes the current to flow thru the primary winding of the spark coil intermittently, every time the timer closes the circuit. When the timer first closes the primary circuit, the primary current as it increases from zero to a maximum value, in passing thru the primary winding of the spark coil, does not induce a sufficiently high tension current in the secondary winding to produce a spark at the spark plug. This is because of the self induction in the coil which reduces the rate of increase of the primary current to such an extent that the secondary tension is not high enough to cause the spark to jump the spark gap.





When the circuit is opened by the vibrator, however, a spark occurs at the spark plug as the current decreases from a maximum to a zero value. The self induction is still present but its effect is killed by the action of the condenser. Thus, a spark occurs every time the interrupter opens the circuit and because the vibrator operates with such a high frequency, the sparks appear at the spark plug as a shower. The elemental circuit diagram is shown in Fig. 1a. The condensers are connected across the points, where the primary circuit is closed and opened. This serves the double purpose of increasing the abruptness of the breaking of the circuit, thereby increasing the intensity of the secondary spark, and of absorbing the current that would otherwise produce a hot spark at the vibrator points and soon burn them out. This spark, that would be produced without the condenser across the vibrator points, is caused by the self inductance in the primary winding as the current dies out. The current value changes at such a rapid rate when the circuit is broken by the interrupter that the self inductance produces an Electromotive Force which is of sufficient value to send the current across the primary gap at the points, and making the spark.

Jump spark ignition for automobiles can be accomplished by three methods; one in which each cylinder of the engine is fired by means of a separate spark coil, vibrator, and timer, as described above; in the second method, instead of providing each coil with a vibrator of its own,

a single vibrator, called the master vibrator is provided; and the third method has the master vibrator, a master coil replacing the individual coils for each cylinder, and what is known as a distributor.

The first method is as described, and connections as shown in fig. 1 a. This method is now obsolete and not used in any machines excepting those which may be still in existence and which were of the first manufactured. Mention is made of it here, however, because it is historical and is one of the steps in the development of electrical automobile engine ignition.

The second method in which a master vibrator is provided for use with four coils, is shown in fig. 1b. All four condensers C1, C2, C3, C4, have one of their terminals connected to the master vibrator at pc, and each one has its remaining terminal connected to that end of its own coil which is wired to one of the contacts of the timer T. Thus, both the master vibrator contact and one timer contact have a condenser connected around them. The path of the discharge current from condenser C1 may be traced from the lower side of the condenser terminal pc; to winding of master vibrator coil, mv; to battery connection, pv; to battery A; to frame of car and engine; to common connecting wire to terminal, ps, of the left hand coil; to primary winding included between ps and pl; back to the condenser. The discharge circuit of any other condenser can be traced in a similar manner.

The master coil has a single winding, and is there-

fore smaller than the double wound induction coil and is comparatively inexpensive. It resembles a kick coil to which a vibrator, V, is added. The timer in this case has its rotor, r, insulated from the other parts of the apparatus. The current from the battery passes thru the master vibrator and switch, h; to the rubbing contact piece of metal, q; which is fastened to an insulated part of the timer; to metallic portion, r, of the rotor; to K1, K2, Ks, or K4; to each primary coil; to engine frame; and back to the battery. Current from the secondary winding of each coil passes from, S, to the insulated electrode of the corresponding spark plug; across the air gap to the uninsulated electrode, and thence thru the engine to the primary-secondary terminal, ps.

In the third method, there is a master vibrator, a master coil, and a distributor. Distributors, or secondary commutators, are devices used for delivering the high tension current generated in a single induction coil, the master coil, to the spark plugs. Except for the rotor of the timer, T, as shown in Fig. 1c, the primary circuit is identical with that for a single spark plug. The rotor of the timer has as many contacts as there are spark plugs, and the primary circuit is closed at the single, insulated, contact piece, k. The high tension terminal of the spark coil, s, is connected to the rotary arm, d, of the distributor. This arm revolves about W, and is insulated from all other parts of the apparatus. The spark plugs are connected to

stationary insulated terminals 1, 2, 3, 4 of the distributor. As the distributor arm turns, its end passes over these terminals, either making contact with them or coming very close to them. The rotor, r, of the timer and the arm, d, of the distributor rotate at the same speed, so that when the timer closes the primary circuit, the end of the distributor arm is over one of the terminals 1, 2, 3, or 4. The high tension current passes between the distributor arm and the terminal that it is over, and is thus directed to the corresponding spark plug. The free end of the distributor arm is broadened circumferentially in order that some part of it will always be over one of the corresponding terminals when the timer closes the primary circuit, altho the contact piece, k, of the timer is rocked thru a considerable arc to vary the time of ignition. Some manufacturers have the distributor contact points move thru an arc equal to that thru which the contact piece moves. This allows them to have a narrower distributor arm and still have the distributor arm over the proper contact point when the primary circuit is closed by the timer.

Spark coils of both the non-vibrator type and the vibrator type are used in conjunction with a distributor. In practice the timer and distributor are mounted on the same shaft as a general rule.

Owing to the fact that the ignition circuit of a four cylinder engine is closed twice in each revolution,

and with engines of a greater number of cylinders the rate increases, there is a great consumption of battery power; and, in order to escape the annoyances of frequent recharging of storage batteries or the replacement of primary cells, various forms of mechanically operated current generators are often employed.

Most of the generators used directly for ignition in automobile work are synchronously driven and generate an alternating current; permanent magnets being used to produce the field. Such machines are called magneto-electric generators, or simply magnetos. With rare exceptions, there are embodied in their construction, a device for breaking the primary current, and a distributor for distributing the secondary current; consequently, if the magneto delivers a low tension alternating current, it needs only one spark coil for a multi-cylinder engine. The only exception that is prominent is found in the magneto of the Ford car, which, while synchronously driven, discharges a high frequency alternating current thru a timer driven by the engine to individual spark coils of the vibrator type.

Magnetos are divided into two general classes, low tension and high tension. In jump spark ignition work a low tension magneto delivers a low tension current to a separate induction coil; a high tension magneto either has the induction coil carried inside the magneto, or it has a secondary winding directly over the primary winding of the armature, and thus delivers a high tension current without

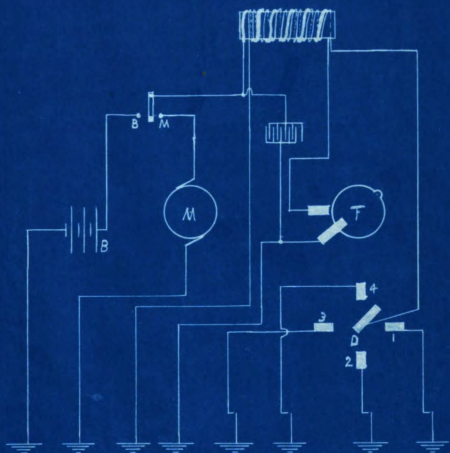


Fig. 2.

any outside apparatus. In other words, the high tension magneto is self contained.

Many magnetos are arranged for dual ignition, using for the battery ignition system the same spark plugs that are used for the magneto ignition system. In that case the contact breaker of the magneto when the battery ignition system is used, serves to break the primary current of the battery, and the distributor of the magneto distributes the high tension current coming from the spark coil of the battery system. Sometimes a separate contact breaker is provided for the battery current. Fig. 2 shows a diagram of a Remy Dual Ignition System, and is typical of the dual ignition system in general.

Sometimes a system known as the Double Ignition System is used. As a rule in such systems, the magneto ignition system and the battery ignition system are entirely independent of each other; each system having its own spark plugs, coils, timer, and distributor.

Another system which is gaining in popularity with a few certain manufacturers is the Multipoint Magneto Ignition System. In this system, there are two spark plugs for each cylinder, sparked simultaneously by the magneto. One way by which this is accomplished is to fit the magneto with two distributors, each serving its own set of spark plugs. Two separate magnetos have also been used and are being used for this purpose, and an additional independent battery ignition system is used, to form with one of the



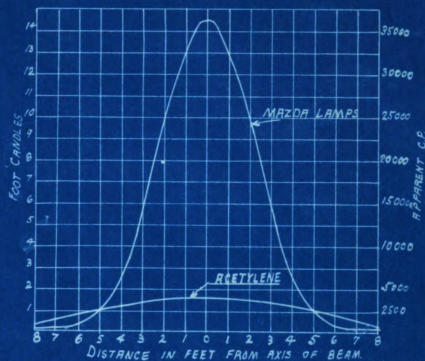
magnetos a dual system, the engine will have three ignition systems, or a Triple Ignition System, as it is called.

The advantage of a multipoint ignition is that with the two points of ignition properly located, the time required for the complete inflammation of the explosive mixture will be reduced and consequently greater power will be delivered to the engine crank shaft. This system is used to a great extent at the present time on cars for the race courses, because there the time for the mixture to completely burn is short and anything which will accomplish fast combustion is a very desirable feature.

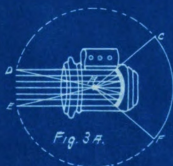
## LIGHTING

That electricity may well be considered the successor of gas and oil in the lighting of automobiles is acknowledged. So generally is it being used that every well appointed car is thus equipped. Not only does it lend refinement and taste to the car on which it is used, but it possesses advantages that are essential to luxury and comfort. The simple pushing of a button produces a superior illumination at any and all times, regardless of the rate at which the car is moving. The annoyance of climbing out in the mud and rain to light lamps is eliminated. A portable safety trouble lamp removes the danger incident to the use of matches around inflammable liquids and vapors. Oil and smoky lamps, features in evidence with non-electric systems, are entirely lacking. Efficient adjustable reflectors allow the concentration or spreading of the light. By the use of dimmers, any desired degree of illumination can be secured. Any adjustment of the lamp can be absolutely maintained and is not affected by vibration due to the roughest road, nor is it possible that the lamp be extinguished by the wind.

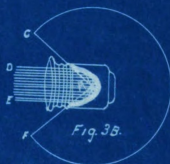
The economy of electric lighting is vastly superior to all other methods. On account of the great heat and the necessity for the ventilation of the gas flame, it cannot be placed near the reflector, and for this reason, only a small portion of the light is reflected. In Fig.3, A represents a gas lamp in which only the light between



COMPARISON OF ILLUMINATION PRODUCED BY ELECTRIC AND GAS HEADLIGHTS.



SHOWING THAT ONLY 25 PER CENT OF THE LIGHT IS REFLECTED IN A GAS LAMP.



SHOWING THAT 75 PER CENT OF THE LIGHT REFLECTED IN AN ELECTRIC LAMP.

points "c" and "f", or about 25% of the total, is reflected.

The electric lamp requires no ventilator and gives off very little heat, and can, therefore, be placed in a deep reflector, so that nearly all the light is reflected, as shown in B, Fig. 3.

To obtain reliable data on the characteristics of both gas and electric head-lights, a number of photometric tests were run on each, by members of the National Electric Lamp Association.

Gas headlights on test were of the latest design having in addition to the regular reflector, an annular reflecting surface between the flame and the front of the lamp. The burners were of the common variety rated at  $5/8$  cubic feet per hour. These burners actually consumed 1.07 cubic feet and gave an average maximum horizontal candlepower of 29.8.

The electric head lights were of the usual parabolic type, the actual diameter of the reflectors being  $8\frac{1}{4}$  inches. The lamps used were "mazda" head light lamps of 21.4 candle power consuming 21 watts.

Readings were taken 50 feet from the lamps across the plane of the axis of the beams, in each case at intervals of 1 foot. Determinations of illumination in foot-candles were made and the candle power computed, the results being shown by the curves in C, Fig. 3, in which the illumination curves are shown for two electric head lamps mounted 30 inches between centers and also for two gas lamps similarly mounted.

It will be noted from the curves that the electric lamps give a much closer distribution and do not project light where it is not necessary. The results show an illumination ahead about ten times as great with the electric head lights as with gas.

There are three distinct systems in use, namely, the straight storage battery system, the generator and battery system, and the alternating current magneto system.

(1) The storage battery system requires that the battery, at intervals varying according to the service required, be charged from an external source.

(2) The generator and battery system operates the lights when the car is running or standing still. The battery is automatically charged while the car is moving above a certain rate, which eliminates any charging costs.

(3) Especially designed magnetos furnish lighting current while the car is in motion. During stops light is supplied either from a straight storage battery system or combination oil lamps.

With the straight storage battery system of lighting the battery is the sole source of energy, a six volt system being used almost exclusively. This is especially true of side, tail, and meter-light equipment. It is quite popular, also, as a complete outfit, including head, side, tail and meter-lamps, and, in the case of a limousine car, interior dome and bracket lamps. In connection with this last equipment, however, the energy

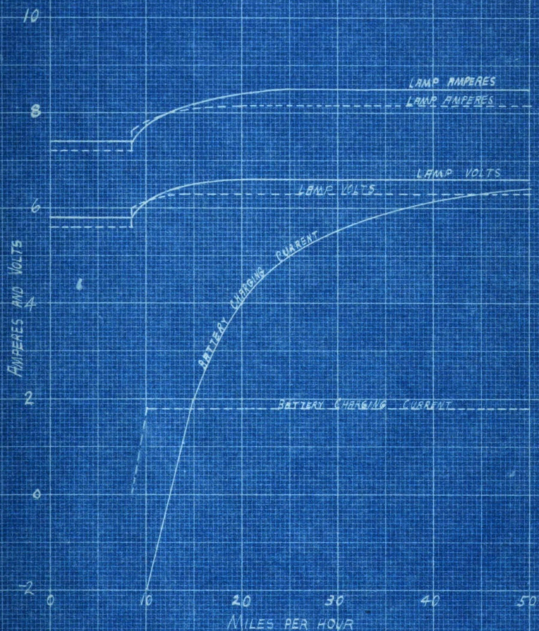
requirements are such as to recommend an electric generator system.

The amount of light that it is practical to use, of course, depends upon the size of the battery. There are maximum and minimum limits in this respect and a unit of 60 ampere-hours appears to be the smallest one to be recommended, while owing to bulk a 120 ampere-hours capacity is as large as is convenient to carry.

Batteries such as are manufactured for ignition service are not recommended for lighting purposes. They are not suited for a high discharge rate and deteriorate rapidly when so used. The principal difference between batteries designed to give a slow discharge and a quick discharge is found in the plates - the ignition type of battery having a few thick plates, while the lighting battery has many thin plates in order that it may have a large plate area per ampere discharged.

The battery system in question is suitable where the energy demand is such as to allow a reasonable operating period. This demand is governed more or less by the expense and difficulty connected with the charging of the battery. To eliminate the charging consideration and also to increase the lighting capacity, the electric generator system has been developed.

In electric generator systems the essential features are (1) generator, (2) battery, (3) some means of regulation, (4) reverse current switch.



REGULATION OF AUTOMOBILE GENERATORS FOR LIGHTING  
 SOLID LINE CURVE, BUCKING SERIES FIELD TYPE  
 DOTTED LINE CURVES, SLIPPING CLUTCH TYPE

The basic element of a complete system is the generator. A shunt wound machine, on account of its characteristics, is generally employed. There are also permanent magnet types in use. Generators should be enclosed and to a reasonable extent impervious to dust, oil, and water to insure reliability. The shape and size govern largely the location of the dynamo, which should preferably be adjacent to a revolving shaft. The most logical and convenient place is somewhere under the hood.

The method of drive should be positive in its nature. Silent chain and gear drives are to be recommended; friction and belt drives frequently cause trouble due to slipping.

Since the storage battery must handle the loads at low engine speeds, or when the motor is standing still, it must be of sufficient capacity to fulfil the demand upon it.

Perhaps the most important feature of the dynamo is its regulation, ie, uniformity of voltage over a wide variation in driving speed. The various methods of accomplishing this regulation can be classified under three heads; namely, mechanical, electrical, and thermal, with perhaps a fourth division of electro-mechanical.

The mechanical method takes advantage of slipping belts or clutches. In this manner the speed of the armature is kept constant which assures a practically constant voltage. An example of mechanical control is the Gray and





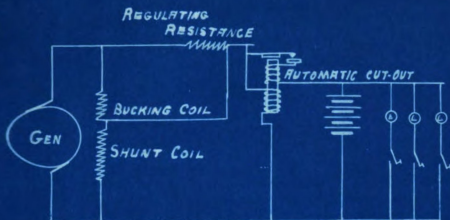
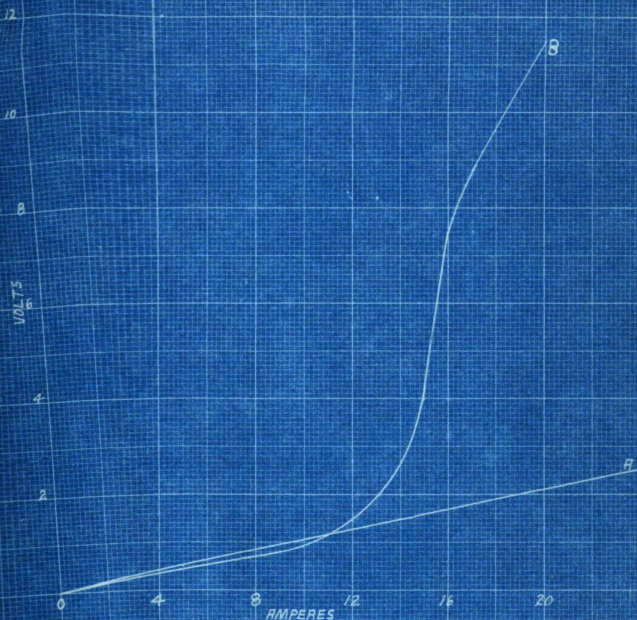


Fig. 4

### CIRCUIT CONNECTION OF RUSHMORE DYNAMO.

THE SHUNT FIELD COIL IS CONNECTED BEYOND THE BALLAST COIL, AS SHOWN, SO THAT IT RECEIVES CURRENT AT ALL TIMES AT THE CONSTANT VOLTAGE OF THE BATTERY. THE OTHER WINDING, OR BUCKING COIL, IS CONNECTED AS A SHUNT ACROSS THE IRON BALLAST COIL, REGULATING RESISTANCE, THE RESISTANCE OF THE BUCKING COIL IS CONSIDERABLY GREATER THAN THAT OF THE BALLAST COIL WHEN THE LATTER IS COLD OR ONLY WARM, SO THAT AT LOW ENGINE SPEEDS PRACTICALLY ALL OF THE CURRENT GENERATED PASSES DIRECTLY TO THE BATTERY AND LAMPS AND THE MACHINE ACTS AS A SIMPLE SHUNT DYNAMO. HOWEVER, AS SHOWN IN FIG. 4, THE IRON WIRE WILL ALLOW ONLY A CERTAIN NUMBER OF AMPERES TO PASS, AFTER WHICH IT SUDDENLY INCREASES IN RESISTANCE, CAUSING THE BUCKING COIL TO COME INTO PLAY, AND CHOKES DOWN THE TOTAL FIELD EXCITATION WHICH REDUCES THE TERMINAL VOLTAGE. IT CAN THUS BE SEEN THAT THE OUTPUT OF THE DYNAMO CAN BE ADJUSTED TO ANY VALUE DESIRED BY SIMPLY EMPLOYING AN IRON WIRE OF SUITABLE DIAMETER IN THE BALLAST COIL.

THE AUTOMATIC CUT-OUT OPERATES AS PREVIOUSLY DESCRIBED. THE RUSHMORE IS USED ONLY FOR LIGHTING BUT THERE SEEMS TO BE NO REASON WHY THE SYSTEM OF REGULATION COULD NOT BE USED ON GENERATORS FOR SUPPLYING CURRENT TO STARTING SYSTEMS AS WELL AS LIGHTING SYSTEMS.



CURVE 'A' SHOWS PERFORMANCE OF GERMAN SILVER OR OTHER MATERIAL WHOSE RESISTANCE DOES NOT INCREASE WITH TEMPERATURE.

CURVE 'B' SHOWS HOW THE RESISTANCE OF AN IRON WIRE REMAINS CONSTANT UP TO A CRITICAL POINT, AFTER WHICH NO MORE CURRENT, PRACTICALLY, CAN BE MADE TO PASS THRU IT.

"RUSHMORE SYSTEM OF CONTROL."

Davis System, where a clutch and centrifugal governor are used.

Electrically operated devices which tend to distort or weaken the field, comprise the electrical methods. The Westinghouse System in which there are two electrical fields, which oppose one another as the speed of the dynamo increases is an example of electrical control.

Thermal regulation takes advantage of a peculiar property possessed by iron, of increasing greatly in electrical resistance at a certain critical temperature just below the red heat. Below this critical point the resistance is practically constant; at and above this temperature, the resistance increases enormously with each degree rise in temperature. The curve in Fig. 4 shows this peculiar characteristic.

The electro-mechanical method combines the principles of two of the above mentioned. Centrifugal devices in combination with field resistances serve as the voltage governor. Some machines also employ a load regulator, which increases the field current as more lamps are turned on.

The reverse current switch disconnects the generator from the battery when the speed of the car falls to such a value that the battery voltage exceeds that of the generator. This operation prevents the battery from discharging thru the generator.

When it is desired, the generator can be used also for ignition purposes thus taking the place of the magneto; however, the necessary timer and coil must be employed.

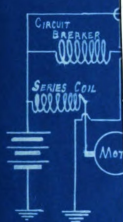
The alternating current magneto system has been installed and gives fair service with certain limitations. The magneto employed generates a low tension alternating current which supplies energy for lighting and ignition. The storage battery cannot be charged from the generator because of the nature of the current produced. When the engine is not running, either a relay or hand operated switch disconnects the magneto from the lighting circuit and at the same time connects the storage battery to the line. The saving resulting from the use of this system is based upon the fact that the storage battery is called upon to furnish energy only while the magneto is not in operation. The popular Ford car furnishes an example of lighting by the alternating current magneto system.

## STARTING

Cranking an automobile by hand has been a source of great inconvenience and personal injury. To alleviate this difficulty, many forms of starters operating by means of compressed air, gas, or springs have been devised, some of which have been fairly successful. The need and demand for a mechanical starter has long been felt, and the use of the storage battery for lighting purposes on automobiles soon led to the application of this energy, also, for starting. During the past four years this type of starter has been so far perfected that today nearly every modern automobile has an electric starter incorporated in it.

The employment of electricity for starting has the advantage of also supplying current for lighting and ignition as well, until today the electric starting system is inherently part of a combination system which takes care of the lighting and the ignition as well. It would seem therefore, that electricity would be universally used for starters, save for the fact that there are some objections, such as high cost, maintainance, and the considerable mechanism necessary, that offset more or less the advantages accruing from its three-fold use.

There are numerous electric starting systems, and they may be classified according to the methods of obtaining current for starting, lighting, and ignition, and the power element of the starter, as: (1) The one-unit system in which a motor-dynamo in a single unit fulfills the three-fold



CONNECTION D  
"DELCO"

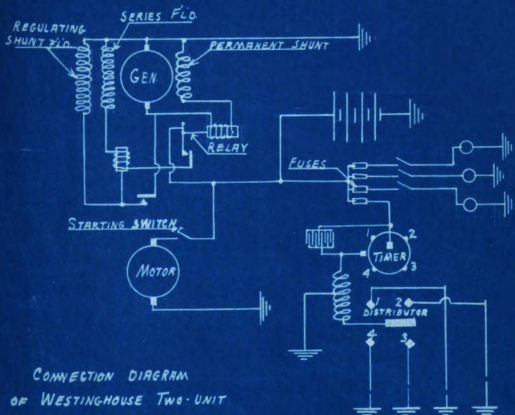
THE DELCO SYSTEM IS AN ELECTRICAL SYSTEM OF VOLTAGE AND TWO COMMUTATORS FOR TOGETHER WITH A SERIES COIL WINDING WITH A SHUNT FIELD WINDING WITH A SHUNT FIELD WINDING. THE STARTING BATTERY ONLY WHEN THE THE REGULATING RESISTANCE CENTRIFUGAL GOVERNOR CAUSE. RESISTANCE IN THE SHUNT FIELD GENERATED.

THE CIRCUIT BREAKER IS GROUNDED. IT DOES AWAY WITH THE SYSTEMS. IN THIS SYSTEM, AS A CUT-OUT IS NOT NEEDED, THE VOLTAGE CONSTANT AT ALL SP THE TIMER AND COIL ARE



TH STARTING MOTOR AND BY A SHUNT FIELD WHICH VOLTAGE BECOMES TOO HIGH. VALUE, THE CURRENT BY ITS ACTION CLOSE VE CLOSE REGULATION PEOPLE CLAIM IT IS D BY RESULTS. UP THE VOLTAGE BEFORE SERIES WOUND.





CONNECTION DIAGRAM  
OF WESTINGHOUSE TWO-UNIT  
STARTING AND LIGHTING SYSTEM  
WITH OPPOSING FIELD REGULATION.

THIS IS A TYPICAL TWO UNIT SYSTEM, WITH STARTING MOTOR AND GENERATOR SEPARATE. REGULATION IS EFFECTED BY A SHUNT FIELD WHICH OPPOSES A SERIES FIELD, WHEN THE CHARGING VOLTAGE BECOMES TOO HIGH. WHEN THE VOLTAGE RAISES TO A PREDETERMINED VALUE, THE CURRENT WHICH FLOWS CAUSES A SOLENOID TO ACT AND BY ITS ACTION CLOSE THE BUCKING FIELD. SUCH A SYSTEM CANNOT GIVE CLOSE REGULATION AS CAN BE PLAINLY SEEN, BUT THE WESTINGHOUSE PEOPLE CLAIM IT IS CLOSE ENOUGH, WHICH CLAIM IS SUBSTANTIATED BY RESULTS.

THE PERMANENT SHUNT IS USED TO BUILD UP THE VOLTAGE BEFORE THE RELAY CLOSES THE CIRCUIT. THE MOTOR IS SERIES WOUND.



purpose above.

(2) The two-unit system which may be divided into two classes: one in which the motor and dynamo are combined in one unit, with a separate magneto for ignition, and, one in which the motor and dynamo are separate, the latter being arranged to operate the ignition system when not running on the battery.

(3) The three-unit system in which a motor, a dynamo, and a magneto are all separate.

In designing starters there are several conditions to be considered in determining what voltage shall be used, especially as the starter problem is somewhat different from the ignition and lighting requirements as to voltage, and one battery is usually employed for all.

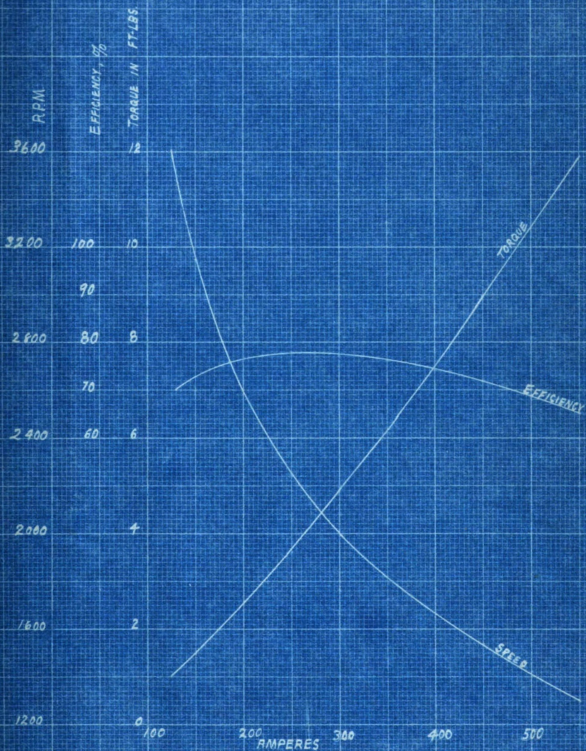
The pressure used on the different lighting and ignition systems is six volts, and were it not for the problem of cranking, there probably would not be any reason to change. This low pressure has the advantage that it is easy to protect the circuit from electrical leakage.

Six volt lamps are manufactured with less difficulty than those designed for higher pressure, and they are to be obtained anywhere. The weight of six volt batteries is less than that of the higher voltage type. Were it not for these considerations, starting motors would be designed for higher pressures as they are smaller and consequently lighter. High voltage for the motor does not necessarily mean high voltage for the generator and lights.



There are three general combinations: 1, All one voltage, either 6, 12, 16, or 18 volts; 2, Generating and starting at 12, 16 or 18 volts, and lighting at 6, 8, and 16 volts respectively; 3, Generating and lighting at 6 volts, and starting at 24 or 30 volts.

The power required for turning over the average engine, will range from one-half to one horse-power. It is therefore evident that, if the lighting generator is to be used as a starting motor, and at its normal operating speed, it will require an extremely heavy machine. In order to reduce this weight, a special driving arrangement might be furnished which would allow the generator to operate at engine speed when being driven as a generator, and allow a considerable speed reduction from the generator to the engine when being operated as a motor. This implies a low-speed generator and a high speed motor, which, for efficient design, necessitates double windings and commutators. Due to the general complication of this arrangement, the scheme of using a separate starting motor is to be preferred. This motor can have its proportions best worked out for its operation as a motor, and without the use of any inactive material, which would be necessary in a combination machine. In order to reduce its weight to the lowest possible amount, it should be operated at the highest speed consistent with the use of efficient gearing between the motor and the engine, the normal operating speed, in actual practice, being between the limits of 1000 and 2500 revolutions per minute, the higher speeds



CHARACTERISTICS OF A SERIES WOUND STARTING MOTOR

being used where the weight is the paramount consideration, and the lower speeds being used where a very quiet drive is desired.

From the point of view of the design of the motor, there are no particular characteristics required other than those obtained with a series motor. The efficiency should be as high as is consistent with light weight, and the lock torque must be such that it will easily crank the engine in winter even when starting conditions are extremely severe. The motor must be able to start the engine from dead centre and be powerful enough to overcome back-fire.

In producing electrical energy the generating equipment must be highly efficient. It should be designed to maintain a constant voltage, as required for lamps and battery, even with widely varying engine speeds. Large output at low generator speed is one of the most desirable characteristics of a motor car generator, as this permits the carrying of the full lamp load when the car is operated at a low rate of speed. Large output at intermediate or average city driving speed is essential in order to restore to the battery the current consumed by the lamps when the car is left standing with the lights burning and the engine idle, for any appreciable length of time. The large output at low speed also compensates for the frequent use of the starting motor. Furthermore, large output at intermediate or average city driving speed is essential to meet winter conditions, it being a recognized fact that storage batteries

in cold weather do not give their rated capacity, losing their efficiency in proportion to the temperature.

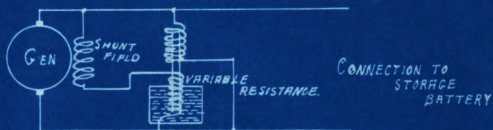
As was found true in the purely lighting system, so, in the case of the combination system, its operation must entirely be automatic. Means must be provided for connecting the dynamo to the battery when speed proper for charging has been reached, and for disconnecting the dynamo from the battery when the speed is reduced to a point where a reversal of current is about to take place. Such a feature is at present incorporated in all properly designed lighting and starting systems now on the market.

In some systems, the connecting and disconnecting from the battery is accomplished by a centrifugally operated switch. The dynamo speed which corresponds to a correct voltage for charging is predetermined, and a centrifugal device is set to close the circuit at this time, and to open the circuit when the speed falls below a safe point. The more common method, however, to accomplish this operation is by means of an electrically operated reverse current switch. This switch or relay, consists of two windings, one of high resistance which is permanently connected across the armature terminals. The current coil or coarse wire winding, is in series with the circuit between the generator and the storage battery, which circuit is opened or closed by the action of the two windings. When the engine is started, the generator voltage builds up and when it reaches the desired value, a current passing

thru the high resistance winding produces enough magnetism to close the relay which in turn closes the circuit thru the coarse wire winding, thus connecting the generator and storage battery. The current flowing thru the coarse wire winding increases the pull on the relay armature, and gives a good contact of low resistance at the contact points where the charging circuit is closed. When the generator slows down and its voltage drops below that of the storage battery, the battery sends out a reverse current thru the coarse wire winding, which kills the pull on the relay armature and permits the relay spring to open the charging circuit.

As in the case of the automatic switch for connecting to the battery, the more difficult problem in controlling dynamo output has been accomplished by means of both mechanical and electrical devices.

Considering first the mechanical types of control, we have slipping clutches of different design. One manufacturer uses a clutch composed of two members, one of which is rigidly attached to the dynamo shaft, and the other to some convenient drive shaft. The clutch members are held together by spring pressure, and, as the speed of the driving member increases, this spring pressure is neutralized by means of centrifugal governors, which oppose the spring tension, and allows slippage between the clutch members, the amount of slippage depending upon the speed of the driving member. This allows the dynamo to be driven at a substantially constant speed, regardless of that of the motor car.



CONNECTION DIAGRAM FOR SECURING REGULATION OF CHARGING CURRENT BY A VARIABLE GERMAN SILVER RESISTANCE OPERATED BY A VOLTAGE COIL.

INCREASING VOLTAGE, LIFTS THE RESISTANCE OUT OF THE MERCURY BATH, INCREASING THE RESISTANCE OF THE SHUNT FIELD CIRCUIT.



CONNECTION DIAGRAM FOR SECURING REGULATION OF CHARGING CURRENT BY SERIES COIL OPERATING A CARBON RHEOSTAT IN SERIES WITH THE SHUNT COIL.

AN INCREASE OF THE CHARGING CURRENT ABOVE A CERTAIN VALUE, CAUSES AN INCREASE IN THE SHUNT FIELD RESISTANCE, PRODUCING THE DESIRED RESULT OF CUTTING DOWN THE CHARGING RATE, AND VOLTAGE.



The regulator adopted by another manufacturer has in it a centrifugal governor which turns at the same speed as the dynamo, and moves a small contact arm over a number of steps of resistance inserted in the field circuit of the dynamo. The greater the speed, the more resistance is inserted in series with the field, so that a substantially constant output is obtained.

There is a much larger number of electrical devices for this purpose. One of the earliest consisted of resistance made of small carbon disks arranged in a tube and connected in series with the dynamo field winding. The disks are normally pressed very tightly together by a spring, and in this condition have a low electrical resistance. The device is so arranged that the armature current of the dynamo passes thru a series coil, which is arranged to pull directly against the spring which compresses the carbon disks. Consequently when excessive charging rates are reached, the pull of the series coil tends to neutralize the spring pressure upon the carbon disks, and the resistance of the field circuit, by the release of this pressure, is increased.

In one system a magnet coil surrounds the upper half of a tube filled with mercury. Within this mercury tube is a hollow iron plunger around the lower portion of which and insulated from it is a coil of resistance wire. One end of this coil is attached to the lower end of the tube, the other being connected to a needle carried in the center of the plunger. The lower portion of the mercury

tube is divided by an insulating tube into two concentric wells, the plunger tube being partly immersed in the outer well, and the needle in the inner well. As the voltage of the battery varies with its condition of charge, the intensity of the pull exerted by the magnetic winding upon the plunger varies and causes this plunger to move in or out of the mercury. When the plunger is at a low position, the coil of resistance wire which it carries is immersed in the mercury, and as the plunger rises the coil is withdrawn. Now, the current to the shunt field of the generator must follow a path leading into the outer well of mercury, thru the resistance wound on the plunger tube, to the needle carried at the center of the plunger into the center well of mercury and out of the regulator. It will be seen that as the plunger is withdrawn from the mercury, more resistance is thrown into the circuit, due to the fact that the current must pass thru a greater length of resistance wire. This greater resistance in the field of the generator causes the amount of current flowing to the battery to be gradually reduced as the battery nears the stage of charge, until finally the plunger is almost completely withdrawn from the mercury, throwing the entire length of the resistance coil into the field circuit, thus causing a condition of practical electrical balance between the battery and generator, and obviating any possibility of overcharging the battery.

Other manufacturers have used double field windings, one portion arranged to oppose the flux generated by the other portion. These opposing or bucking coils are thrown

into play at the proper moment by a series relay inserted in the armature circuit.

The storage battery for use with a starting, or combination starting, lighting, and ignition system, resembles in every respect the battery used for lighting purposes except that owing to the greater demand for current for starting, its capacity must be greater. This increased capacity is obtained by using a greater number of thin plates.

## OTHER EQUIPMENT

One of the most recent applications of electricity on the automobile occurs in the use of electro-magnets for shifting the gears. Instead of shifting the gears by hand lever when different driving ratios are required, the gears are selected and shifted by pressing push buttons on the steering column, thereby completing the circuit thru the electro-magnets, and operating the clutch. A few manufacturers have adopted electric gear shift as special equipment, but up to the present time, because of its newness and the fact that it is not generally understood, and therefore not demanded by the public, manufacturers have not furnished it as standard equipment.

One of the first practical electrical gear shifts on the market is known as the Vulcan Electric Gear Shift.. This consists of two units - the "shifting assembly" or group of magnets attached to the transmission case, and the "selector-switch" or push button group located on top of the steering column, in the center of the steering wheel, where it can be easily operated without requiring the driver to remove his eyes from the road ahead or his hands from the steering wheel.

The electric current required to energize the magnets is derived from a storage battery ordinarily supplied as part of the lighting and starting system on most cars. So slight is the amount of current required to operate the gear shift that it constitutes no appreciable



drain on the energy stored in the battery. In fact it is said that the total current consumed in shifting gears does not exceed .005 of an ampere hour, per shift, or sufficient to supply an ordinary set of lamps for about 4 1/2 seconds.

A selector-switch which is carried on the wheel is made up of a number of buttons, one for each speed and one for neutral, the latter having no electrical connection. The buttons are provided with arched, laminated contacts of copper, backed up with a steel spring and insulated from the button proper. The top of the switch carries a locking plate for locking any button which may be depressed, and also carries an interlock, which makes it impossible to press down more than one button at a time. At the bottom of the switch is a hard rubber base, which carries a copper contact for each button and a common contact to all speeds.

The shifting mechanism consists of a case which is attached to the transmission housing. This case, in turn, carries the magnets or solenoids as they are technically called. These in turn surround the armatures on which the shifting forks which move the sliding gears in the transmission, are mounted. In this case, also, is carried the operating mechanism by means of which the gears are mechanically drawn to their neutral position thru a connection with the clutch pedal.

Assume that the gears are all in neutral and that the engine is running idle. To move into first speed the operator presses button number 1 in the selector group

switch, thus closing one break in the electric circuit to magnet number 1. The circuit is completed when the master switch is closed by the clutch pedal being fully depressed. The operator, having first selected his gear, depresses the clutch, and the final movement of the clutch pedal closes the master switch, completing the circuit thru the magnet or solenoid selected, energizing it and drawing the plunger shaft, to which the shifter fork is attached, into the hollow core of the solenoid.

As the sliding gear reaches the desired position in mesh, its final movement disengages the master switch by means of an automatic tripping device. The clutch pedal is then released, the clutch returns to its normal position and the transmission is in first speed. To pass from first to second speed, etc., the operation is repeated.

Another type of electrical gear shift is being developed by the Detroit Electrical Devices Company. This is a novel departure from the usual plunger magnet type, as in it a rotating magnet is used to shift the gears. It consists of a selector-switch mounted on the steering column just beneath the steering wheel and a shifting device proper which may be mounted at any convenient location along the driving shaft housing, preferably near the transmission.

The selector-switch consists of a movable contact arm which may be moved from one contact point to another for different speeds.

The shifting device resembles two four pole motors, the armatures acting independent of each other. The shifting

and gear selection is accomplished by energizing a pair of opposite poles, thus rotating one of the movable magnets which by a mechanism shifts the desired gear into place.

This type gives great promise of future success but it is as yet in little use. It has the advantage that its installation is not necessarily a part of the original assembly, as it may be installed at any time on a completed car.

With but one exception, little can be said of the other minor accessories which <sup>are</sup> electrically operated and which might rather be classed as novelties than as either luxuries or necessities in an automobile. The one exception is the electric horn, which, from its well deserved popularity, has become a part of the standard equipment. The electric horn operates on one of two principles, viz; either a simple vibrating diaphragm which is caused to vibrate by the intermittent attraction of an electro-magnet, or by the vibration of a diaphragm caused by the action of a rapidly rotating toothed wheel which is caused to operate by a tiny electric motor. The latter type seems to be preferable as there is little difficulty encountered due to sticking of contacts as in the case of the first mentioned type and its tone can be modulated.

Among the other electrical equipment found in gasoline cars might be mentioned electrical heating devices of various kinds such as gasoline vaporizers to assist in starting in cold weather, electric hand warmers which are



applied to the steering wheel in the cold weather, and electric cigar lighters. All these are more or less novelties and their value as a part of the equipment of a well appointed car is questionable.

### CONCLUSION

The above has been compiled after a careful study of the various uses of electricity in motor vehicles and it is considered, by the authors, to be fairly complete. A discussion of the relative merits of the various manufacturers' products has been carefully avoided for reasons apparent.

Today the average motor vehicle placed upon the market is fairly equipped with electrical appliances for the comfort and convenience of the owner. What the future may bring forth it is hard to say, but since simplicity is the watch word in automobile manufacture today, it is safe to say that any additional electrical appliances for the gasoline car must simplify rather than complicate the motor car of the future.



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