As a device for saving time and distance, the automobile bids fair to eclipse all others and to prove itself one of the greatest inventions of our great inventive age. Its motor will, in time, be built cheaper than a horse can be raised, its transmission gear will cost less than a harness, while the body need cost little, if any more than similar parts of horse vehicles.

We have now but the beginning of automobile development and what its growth will be is beyond present conception.

I have found that the automobile is not a new invention; in fact, it is father of the traction engine and of the locomotive. It is one of the devices earliest sought for but latest to be practically and
popularly worked out. We do owe however much for the progress that has been made to those pioneers who have exerted themselves to build mechanical motors for use on the common roads in the face of the great chances of failure and the derision of the world.

As might be supposed, the earliest motor vehicles were those propelled by steam engines, the first attempt, that of least Cugnot, a Frenchman, dating from 1769–1770. Following this, came the proposal of gun-powder engines for such vehicles. Compressed air was also used, notably by Mann in 1822. The first half of the 19th century was marked by many attempts at
motor road- locomotion and many vehicles, particularly omnibuses for public hire, were made and operated between 1820 and 1844 by Hancock, Burney, Church, Fisher, Russell and James. It was James' coach which was first on record to embody a really mechanical device for allowing differential action of the rear, or driving, wheels. This one feature entitles his coach to description as the "first really practical steam carriage built." Most of the others, if the extant details are right or at all correct, must have been, except on straight roads, exceedingly unsatisfactory machines at best.

Public opinion was not with these vehicles. Horse users and stage drivers especially were very bitter
against them. Road Trustees imposed unjust and discriminating tolls, and the ill feeling and prejudice finally resulted in restrictive laws prohibiting a speed faster than three or four miles per hour and compelling a man to precede the vehicle with a red flag. The result was that industry died and did not again exist in England until the passage of the "Eight Locomotives Act" in 1896. Occasional inventors were however making experiments from time to time in France, Germany, and America; but for one reason or another none of these found favor.

It was not until 1896 that we find the marked beginning of the present motor vehicle industry.
developed the small high speed motor which is admittedly the predecessor of the present day practice. For this achievement, Daimler is universally known as the "Father of the Automobile."

By the year 1895 America had seen the prospects of the motor vehicle in those brought out by the Duryea Bros. in 1892 and 1893 and the two cylinder cars of the Haynes Co. In 1896 the first Winton car made its appearance while in the same year more than a dozen Duryea vehicles were completed and the new industry was fairly started on its way. In 1901 two vehicles of particular importance began to attract attention—the Oldsmobile and the Knox. The former because
it was for a time the representative American type and recognized as such in many parts of the world, the latter because of its system of air-cooled motors, which was really the only successful form for a considerable period. These two cars are, as it were, the nucleus of the American automobiles of today, which are judged on an equal basis with all foreign cars.

I might also add that it is on these same general principles that all cars are made.

Thus with this short history and introduction to the "Auto" I will now try to demonstrate to you the new "Haverford" Automobile and hope to give you a general idea of all cars.
The "Haverford's" motor.

The theory of the gasoline motor is that a mixture of air and gasoline vapor is drawn into the cylinders of the engine and ignited, after which the pressure, due to the expansion is caused to perform work in propelling the vehicle.

The essential parts of the motor are the cylinder, piston, crankshaft and connecting rods, fly-wheel, inlet and exhaust devices, ignition arrangement, vaporizer or carburetor, and means of control together with important incidentals, such as lubrication and means for cooling.

1. Cylinder. The cylinders of the Haverford's motor are $4\frac{1}{2}\times 4$" (that is they have 4" stroke with 4½" bore). They are made of cast iron, and provision for cooling with a water jacket is cast
integral with the cylinder. These cylinders are formed with the entire crank-case — each cylinder attached to one-half of it.

Piston. The piston is the moving part which fits into the cylinder and against which the explosive pressure is exerted by the burning gases. It is about one and a half times its diameter in length and is provided with three rings at the head. The wrist pin, by which the piston is attached to the connecting rod, passes through the piston walls, enlargements being provided interiory therefor. It is fixed in the piston by a cotter pin and the end of the connecting rod has a bearing thereon. The head of the piston is flat and is provided with a radiating web. The piston rings are made of cast iron machined to a
diameter one-sixteenth larger than the diameter and then cut as in Fig. so as to be compressed to the cylinder diameter, which leaves them with a tendency to open and causes them to closely fit the cylinder wall. They were fitted closely and carefully to the grooves in the piston so as to make a gas tight joint and prevent the escape of the gas under the ring.

Crankshaft. — The crank-shaft is made of a high steel. Bearings are provided at each end of the crank case and are babbit poured. The common method of attaching the fly wheel to auto crank is used on the "H-5" motor. A flange is made integral with the crank and the web of the fly is bolted to this flange by four bolts which hold it securely and yet permit easy removal.
The crank-shaft is provided with a ratchet at the other end for starting purposes, with a gear for driving the cam-shaft and with the connections for the transmission.

As is customary in two-cylinder engines, the two cranks of the shaft are set opposite, or 180° apart.

Connecting Rods. - The connecting rod attaches the piston to the crank shaft, and are about twice the piston throw in length. They are of U-section, made so that they may catch oil and direct it into the bearings and thus assist in efficient lubrication. The rods are made of steel castings. The wrist end is solid and fitted there with a bronze bushing for the wrist pin. At the crank-end, the construction consists of a removable cap, hinged
at one side and adjusted by a single bolt with castellated nut as in fig. Valve Ports. As can be seen by cut of the motor, the valve ports are at the end of the motor. The valves are same distance from crank-shaft and their stems extend horizontally towards it, where they are conveniently operated upon by the cam on the half time shaft which lifts the valve every second revolution. The illustration here shows the engine with crank case cap removed.

1 = Cam shaft, 2 = \( \frac{1}{2} \) time gear driven by gear on crank shaft, \( 3^\circ + 3^\circ \) = inlet and exhaust Cams which bump \( 4^\circ + 4^\circ \) push rods, which in turn cause the valves \( 5^\circ + 5^\circ \) to open & close at right instant.
Fly-Wheel- The fly-wheel of a gas engine is a sort of necessary evil. Since in a four cycle engine there are three idle piston strokes to one working stroke, a fly-wheel is necessary to store up the energy of the one working stroke and carry the engine steadily through three idle strokes. The fly wheel for the "4½" motor weighs about 80 lbs. In order that the weight may be as little as possible, the fly-wheel is made with the interior surface of the fly wheel rim to be used to form the clutch surface, while in the "Haverford" the fly-wheel is used also as a friction disc to transmit power to other discs on the transmission.

Valve Action. In the four cycle engine, the cylinders serve the double purpose of containing the working charge during one revolution of the Crank-Shaft
and the new charge during the next revolution, thus avoiding the use of the crank case as a charge-containing chamber, in the two-cycle motor, but requiring two revolutions instead of one per explosion as in the two-cycle engine. To accomplish this result with a single cylinder, valves are used both for inlet and exhaust, which are operated ordinarily by a half-time shaft fitted with cams arranged to open their respective valves during substantially one stroke of the four strokes forming the cycle. The exhaust valve is opened about 20-25 degrees ahead of the crank-shaft dead centre, and closed at the opposite dead centre one stroke later. The inlet valve immediately opens, and it closes about 5 degrees after end of the next stroke, one revolution after
the exhaust valve opens. Both
valves remain closed during
compression and working strokes.

Muffler. Connected with the exhaust
opening by piping of convenient length,
is the muffler, consisting usually, of
several (4) chambers generally cylindrical,
and having walls of sheet iron.
This muffler has several times the
capacity of the cylinders, which
permits the exhaust gases to expand
considerably and exposes them to
the cool walls, thus reducing their
volume by cooling,
so that as they
escape to the
atmosphere
they make much
less noise than if permitted to
escape without the intervention of
the muffler. The silencing effect
seems to be largely derived from interference of the sound waves and gaseous impulses. In order to speed up the engine, as on hills or where great power is needed, a cut-out is applied to the muffler and by its means all back pressure from the muffler is avoided.

Vaporizer or Carburetor. Connected to the inlet ports by piping of necessary length is the device for mixing the liquid fuel, gasoline, with the proper proportion of air to make an explosive mixture. There are many different styles of mixers or carburetors, but this carburetor is built on the principle of the most up-to-date methods of vaporization. The gasoline enters the carburetor at 86° and passes up through the needle valve into float-chamber.

When this becomes filled the cork-
Float (77) rises and the lever (79-80-83) which is very light, also rises and the needle valve at the inlet drops and shuts off the supply from the tank until the float-chamber needs a supply.

From the float-chamber a small passage, usually is the case, leads to the spraying tube (71) which is placed so that the air drawn in by the suction stroke of the engine must pass the point of the tube, and in passing suck out and spray the gasoline in the required manner. Since at high speeds the liquid gasoline flows more than proportionately just as compared with the air, a
light valve, located beyond the spray nozzle and made of red fibre, is provided. It is closed by a spring and opened by increased suction as the speeds increase and thus it admits air in proper quantity to compensate for the increased amount of gasoline. There is a throttle at the top of the carburettor just about the mixing space (52) and by means of it, the supply of mixture to the engine can be easily regulated. However, the vaporizing tube (71) must be so adjusted as to let the right proportion of gasoline into mixing chamber—this is regulated by about one and a half turns at (X). Carburetor troubles, I found, are due to improper adjustment at this point, making the mixture either too poor or too rich.
Subrivation. It is now pretty generally recognized that auto cylinders require oil of the highest quality, and that cheap and dirty oil sometimes sold as gas engine oil, is not suited for this work. Good auto-oils usually have a fire-test ranging from 600–800 degrees.

In order to carry the oil to the cylinder, many kinds of apparatus are used. But as is getting to be the practice, the Haverford's motor has an oil pump used in connection with it and which provides for the necessary supply of oil. The pump is driven from the cam shaft by a mitre at the bottom of the vertical shaft on the right reducing thereby all worm gearing.
and the other vertical shaft. On this vertical shaft there is an eccentric operating on a cross head, which reciprocates the plungers lying horizontally along the bottom (EE). At each end of these plungers is a loose sleeve, the sleeves and plungers being retarded in movement by clamping spring. When plungers have moved to right as far as they will go and are reversed, the sleeves are retarded thereby, allowing oil to gather in between the sleeves and the plungers. This amount of oil is carried into the
pump chamber when the plungers start back. It squeezes out the oil between the sleeve and plunger, and draws it into the pump chamber. The motion of the plunger is then continued in the same direction until the operation is repeated. This is a measurer of oil. There is a pipe connecting the crank case of the engine with inside of oil pump, thereby absolutely equalizing the pressure in these two compartments.

All these plungers and working parts are submerged in oil and therefore work easily. One filling of this oil pump will last about the whole of a summer.

The other parts of the automobile are for the most part kept greased by grease or oil cups.
Water cooling. While there can be a loss due to excessive cooling of the cylinders by water, it may, with little trouble be kept at about 212° which is the hottest water, unconfined, can be made. Since water in boiling absorbs a great volume of heat, commonly termed latent heat, in its conversion into steam, it is especially adapted to the work of cooling. An increase of work on the part of the engine, with consequent increased development of heat, simply increases the rate of boiling without increasing the temperature appreciably, and thus avoids warping the cylinder wall or vaporization of the lubricating oil.

The Haverford's system of cooling like many others, which can be easily made that way or account of the frame and other things, is really
the most efficient cooling system. It consists of a tank or reservoir made in connection with a radiator and placed above the engine. It is piped to enter the water jacket on the underside and to return from the water jacket to the tank on the upper side of the motor, which return carries off any steam that may be formed in the water jacket, which steam being lighter than the water, causes the water with which it is mixed to move rapidly upward out of the water jacket and to be replaced by cooler water from the radiator. This method of circulation is known as the natural or thermo-syphon method and is preferred by many designers on account of its simplicity. Since an auto engine of large power
develops much heat, a goodly quantity of which passes away through the cooling system, it is quite evident that the water in the tank will soon become boiling hot unless provision is made for cooling it by the air through which the vehicle passes. The Heavenfoot's arrangement follows the common types, which employ pipes either plain or with radiating ribs, the latter type. With this method a great many square-feet of cooling surface can be gotten into the radiator.

Ignition System. One of the most important features of the gasoline engine is the ignition. It is also the most delicate, and therefore the first place to look for the trouble when things go wrong. The system of ignition is the
used on the Haverford's motor. In this system the terminals are stationary, generally from one-sixteenth to one-eighth of an inch apart, and the spark is made to spring across the gap between them by putting terminals in the secondary circuit of a Ruhmkorff or induction coil. This coil consists of a core of iron wire, around which is wound a relatively coarse insulated wire, the primary circuit, through which the current from the source of energy flows. A relatively fine insulated wire coil, the secondary circuit, is wound around the primary coil, but has no metallic contact with it. If the current flowing through the primary circuit is varied in strength...
it creates or induces a current in the secondary circuit. Generally, the
induction coil is provided with a magnetic vibrator (similar to that
used in an electric bell), which makes and breaks the primary
circuit with great rapidity and induces a considerable alternating
current in the secondary circuit. If the two ends of the secondary coil
be brought close to one another, but not quite in contact, a spark will
jump across the gap at each make
and break of the primary circuit, the spark at the break being the
more powerful. For ignition of the explosive mixture in the motor,
a vibrator is used. The spark
passing on the subsequent remaking
of the primary circuit is not strong
enough to ignite the charge. The
Connections for the ignition are shown here diagrammatically below.

1 = splitdork spark coil
2 = storage battery
3 = commutator or timer
4a = spark plugs in the motor
4b =

Another diagram following shows the primary circuit as being completed through a cam on the side of the engine shaft.

(this is not necessary when commutator...
As soon as the side shaft has moved from position shown, the contact with the upper flat spring is broken and the primary current is interrupted, thereby inducing sufficient current in the secondary circuit to make a spark jump across the air gap in the spark plug.

Since the secondary or high tension current of the jump spark system is of sufficiently high voltage (10,000 to 25,000) to jump a gap between the electrodes while the charge is under compression, it will jump a large gap in the open air, and must be carefully insulated. Rubber
covered wire 1/2 inch or more in diameter is commonly used, the wire itself being very small. The plugs are made of tightly rolled mica, with a gap of 1/32 or more between the electrodes or spark-points, and a spark to successfully ignite, under the influence of the resistance of the compressed charge, should have sufficient energy to jump 3 or 1/2 inch in the open air. A leakage of electricity from the high tension circuit can usually be seen in the dark by a slightly luminous brush-like discharge, and indicates a point where the insulation should be improved if the best results are desired. This jump spark method has as its great advantage the absence of any moving parts inside the cylinder.
The source of current is galvanic cells employing a liquid electrolyte. These were sloppy, short lived and very unpleasant to handle, because of the nature of the electrolyte, which was either sulphuric acid, caustic acid, sal ammoniac or something of this nature. Such batteries have been replaced by dry cells packed solid and simply moistened with a sal-ammoniac solution. These are not likely to leak even when placed on their sides because of the small proportion of liquid contained by them. They are cheap in price (about $0.25 each) and because of their universal use in telephones, etc., are purchasable almost everywhere. They deliver their output under a tension of one to one and a half volts and therefore require a less number in series than most wet
cells. The ordinary make and break coil is designed to operate with from 6 to 10 volts and 2 or more amperes, although very satisfactory results can be obtained with much less. The jump coil (the Haverford's coil) is usually wound for four to eight volts and gives best results if the amperage is quite large. Six cells in series is the customary battery, and good practice makes use of two or more series alternately until all are perceptibly weakened, after which two series are connected in parallel or multiple which doubles the strength (amperage), while maintaining the same voltage. As the voltage of the cells decreases, connecting an additional cell in series is generally advisable.
Change-Speed Device

Second in importance only to the motor is the mechanism for conveying its power to the rear axle, or to the propelling wheels. This mechanism consists of: first, a change speed device by which the ratio of motor revolutions to rear-wheel revolutions is varied to meet the varying road conditions, such as hills, mud, sand, snow, crowded traffic or clear level roads; second, of a shaft for a power transmitting device, such as is used in most cars; and third, of a balance gear often called a differential, or its equivalent, by which the power is divided and caused to drive both wheels, while permitting freedom for the purpose of turning corners. The change-speed gear used is of the latest improved friction type.
This form of friction drive is different from the other types in that it is so arranged as to make use of the friction only for such variations in speed.

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The frame of the transmission is suspended at 4 points by means of bolts from cross members attached to frame of car.

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As are necessary below direct drive and secures the advantage of direct drive with out loss for high speed work, the two side wheels, not being at that time connected with the fly wheel, now are they connected.
with the central driving wheel, splined to the main shaft. The wheels above referred to do not rotate at that time and cease to be a moving part of the transmission. This allows the entire power to be delivered direct to the driving wheels of the car. This can be seen in 1st cut. When necessary to change the speed of the car for either hill climbing or in reversing, the two side wheels are brought into contact with the engine fly-wheel and the central wheel, by means of a foot-pedal or lever, and the direct clutch is automatically withdrawn. Through the use of the side lever the central transmission wheel splined to the main shaft is adjusted on that shaft to any
desired position from the centres to the rims of the offside wheels. The perfect alignment of the driving shaft is not altered in any way by the fact that the side wheels are thrown into contact with its central driving wheel through the operation of the foot-lever. The two side wheels are thrown into contact in unison, the thrust of one compensating that of the other and the extra thrust on both wheels being absorbed by suitable roller bearing thrust journals incorporated in the hubs of the two side wheels. An examination of the illustrations will show that each of the side wheels are driven in opposite directions, as they engage diametrically opposite points on the rim of the
fly-wheel, and as the central driving wheel in turning is engaged by both inner surfaces of the side wheels, it will be seen that the power is delivered to it from diametrically opposite points, thus eliminating any side thrusts on the driving shaft. When it is desired to back the car the central driving wheel is shifted aft of the centre of the side wheels. This accomplishes the purpose of reversing the central driving wheel and
rotating the shaft in the opposite direction. By this arrangement the transmission can be used not only as the regular operating brake of the car but also as a powerful emergency brake.

The rocker-shaft shown in the first illustration is located just ahead of the fly-wheel and is supported at either end by bearings on the frame of the car. The foot-pedal lever from this rocker shaft is located at a convenient place in the floor-board of the car.

Lever connections must operate to pull levers forward.

Provide ball thrust bearing to fit crank shaft between fly wheel and engine base.
The levers shown projecting from the sleeves on the inner side of the hub bearings are operated in unison from the foot pedal, to bring the side wheels into contact with the engine fly wheel and the central wheel on the shaft simultaneously. The levers on the rocker shaft which are connected by turnbuckles and rods to these levers must all be in alignment thus making the drawing up more likely to be in unison. This illustration shows direct clutch.
with the engine fly wheel removed. When the central wheel is being moved forward and is near the fly-wheel, this clutch is engaged, which connects the fly-wheel and driven disc positively after which the intermediates are disengaged, leaving direct drive on high gear.

Some of the advantages claimed for this transmission are:
1st. In its simplicity and economy of application.
2nd. In its adaptability to heavy trucks and cars, through the simplicity of operation and absolute control of the load of the engine.
3rd. Its economy of power when driving direct.
4th. Its absolute noiselessness
5th It is a most powerful and satisfactory double acting brake.
6th It will outwear any gear transmission.
7th It is less expensive than any first class gear transmission.
8th There are no gears to strip and wear.
9th It can be shifted by either a hand or foot lever.
10th All parts are constantly accessible.
11th It requires no bath of oil; hence there is no leaking or dripping from that source.
12th There is but one bearing on the driving shaft between the crank case and the differential.
13th It can be used for a side chain drive as well as for a direct shaft drive.
14th - Roller bearings are used throughout.
15th - It can not be injured by careless handling.
16th - It maintains a constant and even load upon the engine.
17th - It starts cars of any weight without jerks.
18th - It is not confined to any limited number of speeds ahead. The speeds ahead are infinite.
19th - It puts less strain upon the running gear of the car than any other transmission.
20th - The friction surfaces will withstand 5,000 miles of usage without showing any appreciable wear and when worn can be replaced for almost nothing.
21st - Its disadvantages are not to be mentioned.
After passing the change-speed gear, the power is transmitted usually to the balance gear, and for this purpose a propeller-shaft transmitting device is used on the Haverford. It is so named because of its resemblance to the shaft used to transmit power from the motor to the screw propeller in boat service. At its power or forward end it is driven by the motor or change-speed gear just as in a launch, while at the rear end it is fitted with a bevel gear of rather small diameter, meshing into a larger (3½) bevel gear on the rear axle or counter shaft at right angles to the propeller-shaft. The bevel gears are encased to hold oil or grease and keep out the dirt, and this casing contributes very largely to good service given by such gears.
Universal Joints. Because of the impossibility of holding the motor at the front of the propeller shaft and the gears at the rear in alignment with each other, it is common to provide the propeller with knuckle or gimbal or universal joints, which, while transmitting power perfectly, permit the shaft to yield and change its direction ten or even twenty degrees. The propeller shaft is provided with a telescopic joint which permits it also to vary in length between ends, and these two accommodations allow the springs of the vehicle to perform their function without interfering with the transmission of the power. These joints which are used on the Havenford are made of heavy bronze and are keyed and fastened to shaft by set-screws.
Radius rod. While with the level gear drive a slip joint on the propeller shaft usually suffices to maintain a fixed distance between motor and the driven axle, an extra strain is thereby thrown upon the level casing, which is only too liable to break, with the other forms of violence it must endure. For this reason a radius rod is used attached to a bearing at either end of the spring support, so as to describe an arc, with the rear axle as a centre, while the springs rise or fall in travel.

Balance Gear and Compensation and its device.

The power of the motor is applied to the centre-divided rotating rear axle, the drive being through a device known as the differential or compensating gear. There is another,
necessary function which must not be omitted—the differential must also be a balance gear. "But it is to say, it must combine with the function of compensation an even or balanced transmission of power to both wheels. Each wheel, so long as it is in motion, must be driven with some degree of power. At no time, on short turns, when one wheel is stationary, acting as a pivot, is it permissible that, say two-thirds of the power, be sent to one drive-gear and one-third to the other. The Haverford's rear axle and differential is very similar to above cut and principles are the same.
As shown in the figure, the bevel drive carries a number of studs which in turn carry bevel pinions. These, in turn, engage a bevel gear wheel on either side of the large bevel wheel. These last mentioned gears are rigidly attached on either side to the inner ends of the centre-divided axle-bar, one serving to turn the left wheel, the other the right. When power is applied to the main bevel gear, causing the vehicle to move straight forward, it may be readily understood that the bevel pinions, secured to the bevel gear, instead of rotating, which would mean to turn the drive wheels in opposite directions, remain motionless, acting simply as a kind of lock or clutch to secure uniform and continuous
rotation of both wheels. So soon as a movement to turn the vehicle is made, at which time the wheels tend to move with different speeds, the resistance of the wheel near the centre, on which the turn is made, tending to make it turn more slowly than the other, as anyone may readily observe, these pinions begin rotating on their own axes. Hence, while allowing the pivot wheel to slow up or remain stationary as conditions may require, they continue to urge toward the other at the usual speed. The principle involved in this device may be readily expressed under these four heads:

1st. When the resistance offered by the two drive wheels and attached gear is the same, as when the
curriage is driven forward, the pinions cannot rotate.

2nd. When resistance is greater on the one wheel than on the other, they will rotate correspondingly, although still moving forward with the wheel offering lesser resistance.

3rd. The pinions may rotate independently on one gear wheel, while still acting as a clutch on the other, sufficient in power to carry it forward.

4th. If a resistance be met of sufficient power to stop rotation of both wheels and their axles, the condition would affect the entire mechanism, and the pinions would still remain stationary on their own axles, just as when in the
act of transmitting an equal movement to both wheels.

Generally for light carriage work the bevel gear differentials carry two pinions but in the Haverford the number is increased to four while in larger vehicles there are six, eight and sometimes more, the pitch and number of the teeth are varied, according to the requirements.

Directly connected with the balance gear is the design and construction of the rear axle. The two half-axles pass through the tubular frames, which are bolted together around the balance gear forming the balance gear box, frame or spider. Each half-axle is a duplicate of the other as is each half of the rear frame work, and each is provided with bearings
at the inner end near the balance gear and at the outer end adjoining the vehicle wheels.

Front Axle.

The front axle of a motor car vehicle differs from the horse drawn vehicle construction in that there is no fifth wheel at the centre of the axle about which the axle turns for steering purposes, although this construction is sometimes used; but on the Haverford each end of the axle is provided with a steering head into which a vertical spindle or neck is journalled, which neck carries the axis of the corresponding front wheel. To this neck is attached an arm for
controlling the direction of the neck; and that the opposite wheels may be steered in unison, an arm on one side is connected with a corresponding arm on the opposite side by a tie bar parallel to the front axle.

It can be readily seen that in turning a corner both front wheels should be so turned that each will describe an arc concentric with the arc of the other; for if both arcs are not concentric, one will be forced to slip sidewise to a greater or less extent, with the result that the tires will be worn and the steering will sometimes be controlled by one and sometimes by the other wheel, with consequent greater "skidding", a very disconcerting eccentricity in the matter of steering. The same result is found in driving straight.
ahead if the steering wheels are not parallel to each other as they should be.

In order that the steering wheels should describe concentric arcs, the steering arms are projected either backward and inward (as on the Haverford) or outward and forward, and the tie-bar is made of a suitable length to hold the wheels parallel for straight driving ahead. This arrangement fixes it so that the inner wheel on a turn will be steered at a greater angle from the centre line of the vehicle than the outer wheel, and will describe an arc of a circle shorter in radius than the outer wheel. It is easily seen that both wheels should steer around a
a common center and that the radius for one wheel in one case must be the width of the vehicle, usually about 5 feet, greater than for the other wheel. The proper angle for these steering arms depends upon the distance between the axles and the distance between the steering head center lines, and is found approximately by drawing a line through the steering head center to the middle of the rear axle.

The forward axle shaft is rigidly secured across the body of the vehicle, and has no movement whatever. At each end it carries a yoke, to which is bolted at right angles to the axle shaft, so as to form a true knuckle joint, a boss one of them conical shape, to fit
The axle box of the wheel, which is suitably secured, as in horse-drawn vehicles, so as to rotate freely; the other being an arm, shaped with a ball end, for attaching the transverse steering link bar. This link bar is arranged to connect the steering arms of both stud axles on the through axle shaft, the connection for the control wheel, placed conveniently to the drivers hand. Steering wheel. The wheel steering device consists of a rotatable post which is fitted with a wheel at its top end, and with a worm arrangement at its lower end.

By this device, the illustration turn of the steering wheel throws the steering wheels to their limit in one direction.
The worm on the steering pillar rotates a spur gear which carries on a spindle, an arm that actuates the steering axles through a drag link. Ball joints between the drag link and the arms at either end enable it to compensate the up-and-down motion of the springs. Since the worm can actuate the gear, while the gear cannot actuate the worm, this type of steering is also irreversible; although as in the former case, vibration may be readily imparted.

Brakes. Second only to ability to go is the power to stop, on which account brakes are most important. Those on the Haverford are drum brakes which consist of bands which operate around the hub of a drum on each rear wheel.
These band brakes are attached at the middle of the band leaving both ends for operation. This insures that no matter which way the vehicle is moving, the brake is equally powerful. These brakes are operated by a foot-pedal lever. Two methods of braking are considered best practice, but one set is all the Havemford needs on account of the braking power of the transmission as is mentioned under that subject.

Wheels. The motor carriage wheels are wooden, of the so-called "artillery" type. These wheels are constructed with wedge spokes set together around the nave, and a hub formed of steel plates at front and rear, bolted through the spokes and holding the axle box in place. This is
almost the same model originated by Walter Hancock, an early steam carriage builder, and is by far the most solid design of wooden wheel possible. It is, in fact, practically of one piece, having strength to withstand sidewise strains that would speedily wreck a wheel used of the type used in horse-drawn vehicles. Another reason why these wheels, which are much smaller in diameter than those of horse carriages, are used, is to save tire expense. Another reason for small wheels is the fact that the motor runs much more rapidly than the wheels, which necessitates gearing and large wheels require a greater difference in such gear ratios than small wheels.
Tires. All automobiles and cycles, and a large number of horse drawn vehicles, use rubber tires. The object is two fold:

1. To secure a desirable spring effect.
2. To obtain requisite adhesion to the road.

The tires on the Haverford are 30 x 3½ pneumatic clincher tires. The most valuable quality of this tire is its resiliency, or the ability to bounce in the act of regaining its normal shape after encountering an obstacle in the road.

The clincher tire is so called because as first constructed, its edges were provided with clinchers or abutments resting against upturned edges of the rim. These tires are also of the double tube type.
Body. As the body was built in
an amateur's spare hours it does
not embody all the best features
of a body made by a regular
body-building firm. But it
has one common feature, i.e., the
operators seat. This was in the
first autos placed well to the front,
as in horse vehicles, but because of
the sudden side-wise movement of
the front end, due to steering, this
seat was found more comfortable
if placed further to the rear. It
is generally conceded nowadays
that the best place for the seat
is as near the middle of the
car as is possible and the
space which was formerly taken
up by the seat is covered by a
bonnet and is occupied by the
motor with its necessary equipment.
Location of the Mechanism. The arrangement of the motor etc. can best be seen by looking at the illustration of the car in the front of this book.

Springs. The comfort and durability of the auto depends largely upon the springs, although many designers have relied on tires for this service. The half-elliptic type are used on the Haverford and their main advantage is the rigidity sidewise. These springs are fastened to the axles as can also be seen in the illustration and are fastened to the framework at one end, while other is carried by a swinging shackle.

Bearings. The bearings used on the Haverford are of three kinds, plain ball and roller and all give good satisfaction when properly oiled.
Operation. Turn on the gasoline, put on spark (electric current), open throttle and turn and then turn the starting crank. After motor starts, adjust gasoline to give best result.

More, by side lever, the central wheel-on transmission a little ahead of centre of drive wheels and press gently against foot-pedal for moving these wheels against fly-wheel, etc. This throws a load on engine, to overcome which throttle should be opened correspondingly.

As the car moves, feel steering gear to see that it is under control. As speed increases, more central disc forward until direct clutch is thrown in. The operator having followed these directions could run the car and would soon be able to recognize by ear if anything was wrong.