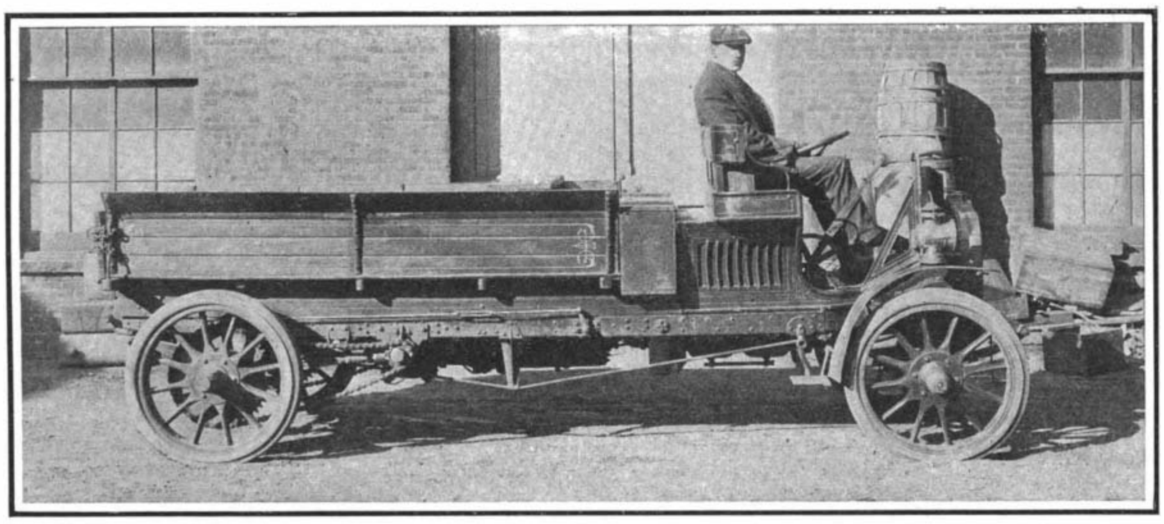
point remained imbedded in the plate. The maximum amount of bulging at the back of the plate, in the line of points of contact, was not over 1.5 inches.

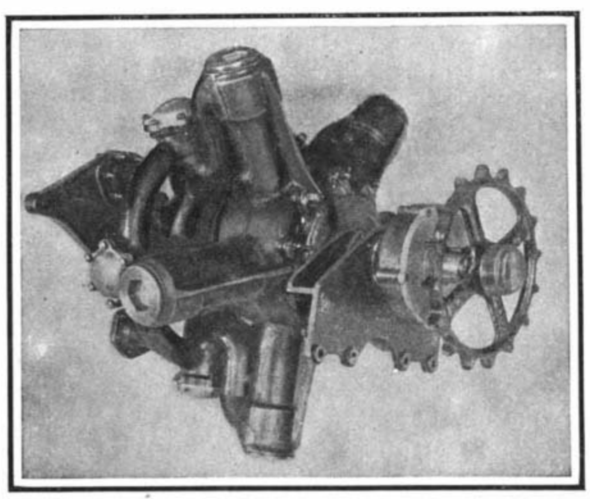
A HYDRAULIC DRIVE SYSTEM.

The fact that the internal-combustion engine depends upon momentum of its moving parts to bridge the gaps between explosions, makes it impossible to start the engine under load, and materially lessens its efficiency as its speed is reduced under load. For this reason it is necessary to provide clutches and variable speed gears, which will permit of reducing the speed at the point of application of the power, while the engine itself operates under such a speed as will yield the highest efficiency. A perfect mechanical variable - speed gear has yet to be discovered, and so far we have been obliged to worry along with systems, so abhorrent to the mechanical engineer, of operating by jerks from one speed to another. From time to time efforts have been made to overcome the difficulty by the use of a flexible medium such as electric or hydraulic drive, between the gasoline engine and the point of application of the power. But, hitherto, the operation of these systems has not been such as to warrant their commercial application.


A 5-ton motor truck fitted with a hydraulic drive system.

A new system has just been developed by Charles M. Manly, who is probably best known for his work with the late Samuel P. Langley in the development of an extremely light gasoline motor for use on the Langley aeroplane. Mr. Manly's transmission is hydraulic; but oil is used instead of water, because of its lubricating and non-freezing qualities. The oil is circulated in a closed cycle by means of a pump driven directly by the internal-combustion engine, and in the oil circuit one or more motors are included, which are located where the power is to be applied and which are driven by the circulating oil. The key to this system lies in a special form of double eccentric, the throw of which may be varied from the central or zero position, in either direction, so as to vary the stroke of the pistons to any degree within the limits of the mechanism.

In the accompanying illustrations we show the drive system as applied to the operation of an automobile truck. The pump which circulates and generates the pressure in the oil is indicated at *A* in the diagram, while one of the motors, of which there are two, one for each of the rear wheels, is indicated at *B*, the other being removed for clearness. It will be observed that the drive system does away with all gearing between the engine and the wheels, with the exception, of course, of sprocket and chain connections between the motors and the wheels. The differential gearing and the brake are done away with, as well as all variable-speed devices. A single lever controls the stroke of the pump pistons, and the pressure of the oil being directly dependent upon the pump stroke, this controls the speed of the wheel motors, and consequently of the truck. The engine may be run continuously at full speed, in fact there is no necessity for changing it for any purpose; setting of the eccentrics in the no-throw position brings the pump to rest, when its stationary pistons will completely block the circulation of the oil, preventing the motor from operating, and thus providing an efficient brake. As the motors are connected "in parallel," to borrow an electrical term, differential gearing is unnecessary, for they will adapt themselves to the variations in load on the two wheels, as the car is rounding a curve; in fact, there can be no more perfect differential system. The advantage of this drive for use on trucks is that it does away entirely with all complicated mechanisms that would require a skilled operator. The truck shown in our illustration is loaded with sand to a weight of 9,000 pounds. It has been in constant use under this load, and under the most exacting road conditions, for over a year, and always in the hands of unskilled operators. The Manly Drive Company keeps this truck so loaded for testing and demonstrating, and frequently brings in a load of an additional ton or two of material over the roughest kind of roads without troubling to remove the dead weight always carried. For this purpose a small gasoline engine, formerly used in a run-about of 16 nominal horse-power, is amply sufficient. Motor trucks now in use for similar work require a 30- or 40-horse-power engine. Makers will admit that for a gross weight of say 10 tons, a speed of 6 miles per hour, grades not to exceed 5 per cent, and average road conditions, the drawbar pull requires only one-fourth to one-third of that power, but the balance is necessary for reserve, especially for starting on up grades. The great advantage of the Manly drive is that the available power can be increased inversely as the speed, the maximum torque being available exactly when it is most needed in starting from rest without increase of engine power, and the maximum engine power being required only under the most favorable conditions, i. e., under the maximum speed of the car or truck with radiator and circulation giving their maximum effect. This is just what is least possible with drive systems at present in vogue for gasoline automobile use, as is evident to anyone who has tried to start his car up a steep grade. The engine must be run up to speed to attain its efficiency, the brake cautiously released to avoid running back, and the clutch as cautiously engaged, even if there be no necessity for a change of gear in such a situation, all of which difficulties are eliminated by the Manly drive on account of the above-mentioned features and the absolute braking effect of the oil under pressure in the system whenever the pump is even momentarily stationary.

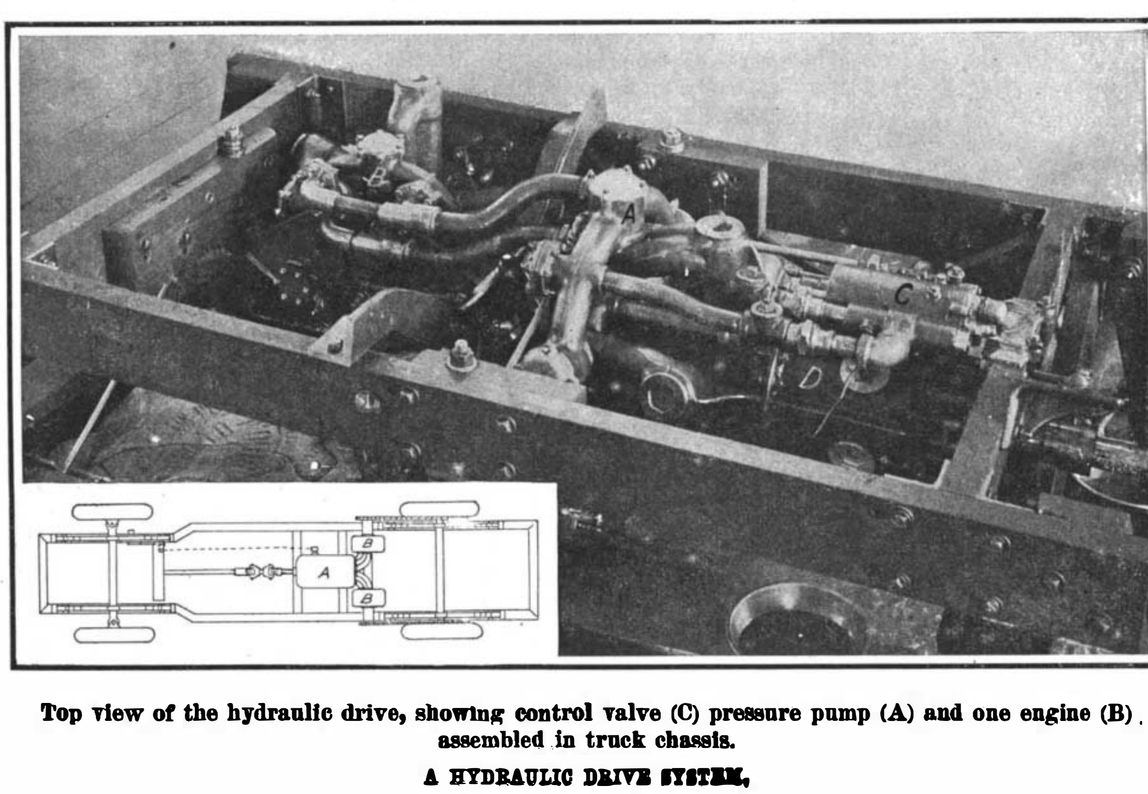

The hydraulic engine. An engine drives each wheel.

In the demonstrations made for the Scientific American, the bulky motor truck with its 9,000-pound load was backed and maneuvered into and out of close corners, both in the yard and in crowded street traffic, with the utmost ease and quiet, and none of the starting and stopping of engine, engagement and disengagement of clutch, and screech of changing gears, so noticeable when an automobile merely draws up to a sidewalk in a crowded street, while quick changes from full speed ahead to reverse were made, which, with the momentum accumulated by the 20 tons gross of car and load, would have torn the teeth out of any known system of change-speed gear.

The driver of the truck, who is shown in the photograph, has never driven an automobile, and would not know how to drive one. All he knows about the auto truck is that when he moves the lever forward, the truck will move forward at a speed proportionate to the position of the lever; that on bringing the lever back to central position, the truck will be brought to an absolute standstill without requiring any brake; and that on further withdrawing the lever, the truck will move backward in the same proportion. It is obvious that the alteration of the throw of the eccentric must be against the pressure of the oil, which would be a laborious and sometimes impossible operation if the actual movement of the parts were effected by the manual lever. This is overcome by the introduction of an ingenious device, by which the oil pressure itself changes the eccentric throw. The hand lever operates only a pilot valve, the casing of which is shown at *C*, admitting oil from the circulation to the eccentric-operating mechanism, and returning to a neutral position when sufficient movement of the latter has been made.

During the entire year of operation, the hydraulic drive system of the truck has required no repairs whatsoever. The mechanism was provided with adjustments, so as to take up any wear of parts, but so little wear has resulted, due largely to the lubrication of the oil circuit, that, in the machines now building, no such provisions for adjustment are considered necessary. The only attention the hydraulic system requires is that at the end of each week a pint of oil must be added to replace the oil lost by friction in the stuffing boxes.

The possibilities of this system for trucking are very alluring. Instead of gasoline engines, kerosene engines could be used. Heretofore, kerosene engines have failed for automobile work, because they do not permit of the variations in speed that are possible in gasoline engines. A number of these automobile trucks could be started from a central station by a skilled man, who would see that the engines were in proper working condition. Once the engines were started running, they could be left in operation the entire day. An ordinary truckman could then drive the machine without giving thought to the engine, his only attention being devoted to the steering wheel and the single lever that controls the starting, stopping, and reversing of the machine. A truckman would be much better fitted for this work than the skilled chauffeur, because he would know better how



Top view of the hydraulic drive, showing control valve (C) pressure pump (A) and one engine (B) assembled in truck chassis.

A HYDRAULIC DRIVE SYSTEM.

to handle cases, where to go for freight at the docks, how to thread his way through congested streets, and how and where to deliver the load, for which work, moreover, the operator sufficiently skilled to control the complications of the present automobile engine is either too expensive or considers himself superior. A single man could have entire control of the running of the machine and the handling of the freight, whereas in ordinary systems a skilled driver is necessary in addition to the usual freight handlers. In case of an accident to the machine, word could be sent to the central station, and a second truck could be sent out to replace the injured one, while the latter was being repaired.

Although we have shown this hydraulic drive system as applied to auto trucks, it will be evident that it is equally applicable to high-speed automobiles. It is not necessary for a man to be a machinist in order to run an automobile thus equipped, because the usual trouble-making gearing is entirely dispensed with, and the possibility of a break is extremely remote. Mr. Manly has suggested that the system could be used in connection with any power system, in which a variable speed is desired. On ocean steamers, for example, the hydraulic power transmission between the engines and the propeller would prevent racing of the propeller when it was lifted out of the water, for the reason that the incompressible oil circulating through the system determines positively the rate of motion of the various parts, and absolutely prevents the pistons from moving at a higher speed than is set by the circulating oil, even when the load is suddenly relieved.

NEW DISCOVERIES ABOUT LIGHTNING.

BY JAMES COOKE MILLS.

While photographs of lightning flashes are not new, such pictures as recently have been taken under the auspices of the Smithsonian Institution are attracting unusual attention in the scientific world. Curiously enough, the investigations which have been conducted along this line were brought about almost by chance. A year or so ago, a letter was received by the secretary of the Smithsonian, inquiring for a publication of the Institution relating to photographic experiments. It was couched in quaint English and written in a foreign hand, its author being Alex Larsen, who a short time before had arrived in this country from Denmark. In his letter Mr. Larsen mentioned incidentally that he had taken some photographic lightning by holding a small camera in his hand and revolving it from side to side. He inclosed a proof of one of his pictures, and inquired if it was of any scientific value.

The idea of taking pictures of lightning with a moving camera, while not new to the officials of the Institution, was considered by them well worth experiment. They opened a correspondence with the young investigator from Denmark, and found that he was more than ordinarily well versed in science, having made a study of chemistry, physics, and mechanical and electrical engineering in his native land. His material resources were limited, and the apparatus he used was necessarily crude, he having conducted his studies and experiments at odd moments from the daily grind of eking out an existence.

The Smithsonian officials deemed young Larsen worthy of assistance, and they appropriated a grant from the Hodgkins Fund of the Institution for the provision of an excellent photographic apparatus, and a sum of money for the construction of a suitable moving device to continue his experiments, and also to pay in part for his support.

The results of this comparatively small outlay have been notable. The peculiar flickerings of most lightning flashes, which the ancients attributed to some supernatural origin, have now been analyzed, and several successful exposures clearly show that nearly all flashes are composed of several discharges following one another at certain intervals in the path made by the first discharge. It is definitely determined, therefore, that a flash of lightning is not one single vibration, as generally supposed, but is made up of numerous small flashes or "rushes."

How rapidly these rushes must follow each other may be imagined from the fact that the flash may be composed of as many as forty rushes, and the duration of the whole a fraction less than half a second. The perpendicular flash shows a broad sheet on the negative, and on the prints from that the distinctive rushes can be counted. The time of the flash is determinable from the known width of the sheet on the plate and the known motion of the table on which the camera is set. According to calculations made by Mr. Larsen, the rushes vary in duration from three one-hundredths of a second to two one-thousandths of a second.

The most remarkable result of these experiments is the discovery of a "black rush" in the lightning flash, that is, a rush not discernible to the eye; and as paradoxical as it may seem, there *is* invisible lightning. To verify and substantiate this, we have only to refer to Fig. 1, a reproduction of a photograph taken September 1 at 9 P. M. The storm during which this flash was photographed began about 7 P. M., with the wind northeast, which is very unusual for Chicago. The wind gradually changed to north and northwest, the temperature being about 24 deg. C., and the barometer varied between 29.89 and 29.92. The flash was obtained when the storm was most severe and while it was raining very hard.

This flash is composed of forty separate discharges, made up of one band, which in all probability is composed of a number of separate rushes or oscillations very close together, and one black discharge. It is this black discharge which makes this flash the more interesting, and the photograph shows it running parallel and on both sides of the first bright rush, the boundary line on the inner side being more plainly marked. From this black discharge issue several side branches on both sides, a large one spreading out over the other rushes quite prominently. These side branches all pointing downward indicate that the black rush was a downward stroke, and they also tend to prove that it must have had a good deal of resistance to overcome. It must have cleared the way for the first bright discharge, which in all probability proceeded from the ground upward. The difference in width of the bright discharge, measured at its lower and upper parts, would confirm this opinion of the experimenter, being nearly twice as wide at the lower part as at the upper part.

An interesting question here presents itself. Have we here two separate discharges with different rates of oscillation traveling the same path? Can such a condition be possible? To the experimenter's mind the most plausible explanation would be that the two discharges occupied two separate paths, one inside the other, one discharge forming, so to speak, a tube through which the other passed. It may also be claimed that the bright discharge is probably part of the dark discharge for some reason rendered more luminous. This explanation may be the true one, although it appears as if the bright flash is entirely separate. The measurements of the width of the lower and upper parts of both discharges confirm this opinion.

Authorities differ in their opinions as to the probable cause of these dark rushes. It has been suggested by some that there really are no black discharges, but what appear as such are excessively bright rushes causing a reversal of the image on the plate. This explanation may be the true one if we understand the word "brightness" to mean increased actinic power of light. In the black discharge represented this chemical effect must have been extremely high, owing to the fact that the smallest hair-like extremities of the side branches are well reproduced on the picture as black, in comparison with the broader and to all appearance more powerful discharges following after.

It was at first thought likely that we had to deal with an interference phenomenon, but the idea was discarded. Then it was suggested that the black discharge was probably due to slow oscillations (the width of it would tend to confirm this), and what appeared as black on the plate would be in reality a dark red discharge on a partially illuminated background. The red, of course, would take black in the photograph. This opinion had also to be discarded for the reason that, if such be the case, the side branches of the dark discharge would have been obliterated by the other rushes following. The effect of halation and solarization was also considered, but rejected.

There was thus but one way to account for the prenomenon, namely, that the flash must have given out light of a wave length much shorter than the wave lengths of visible light, and with a power sufficient to render the portion of the plate struck by it non-sensitive to ordinary light. Such a flash would appear black on a partially illuminated background, or be invisible.

Dark flashes have been observed by the experimenter on several ocasions, and only when raining very hard. They appear to the eye the same as the accidental image produced after looking at a bright flash. Such an image may be retained in the eye for quite a while, but cannot easily be confounded with a real flash.

Fig. 2 was obtained on October 1. We have here a flash composed, first, of two bright discharges close together, then there appears to be an interval of about a fourth of a second, which in all probability was filled in with a number of fainter oscillations (the lines running across seem to indicate that), and at the conclusion of the flash are four bright rushes.

During the summer a new departure was undertaken by Mr. Larsen, the object being to obtain spectrum photographs of lightning. Spectroscopic examinations of lightning have been made by many, but most of these observations have been visual, which at their best can only be rough approximations of the number of lines and their relative positions. An apparatus was constructed, consisting of a camera with a prism fitted in front of the lens, no slot being used, as a lightning flash is a relatively narrow streak of light yielding a practically parallel beam. By means of this arrangement a few photographs have been obtained, one of which is reproduced in Fig. 3, while a spectrum photograph of a spark from a static machine, for comparison, is shown in Fig. 4. The first shows the spectrum of one of those horizontal meandering flashes often seen at the conclusion of a storm of long duration. It differs considerably from the other, several lines being absent. No definite opinion has as yet been offered by Mr. Larsen as to the meaning of the changes of these lines in the spectra of different flashes, because more material must be obtained before a positive statement can be made.

The moving camera apparatus for making lightning flashes is a simple enough device, and has proved satisfactory at all times. A spring motor movement (of the kind used to operate revolving stands for exhibiting goods in show windows) was procured and mounted inside a table specially constructed for the purpose, and a stand for supporting the cameras was fitted to the central shaft.

As the speed of the motor was too slow, the fly-vane shaft was removed and the vane moved to the next shaft, which was lengthened so as to extend under the table. Thus arranged the fly-vane could be made to revolve in a liquid placed in a vessel under the table, thereby preventing much of the vibration and getting a more uniform speed. Fig. 6 shows the arrangement of the apparatus, with the table top removed to show how the motor movement is placed; the fly-vane revolving in the water box beneath. The stand is usually revolved at a speed of one turn in ten seconds, which was found to be the most suitable for ordinary purposes. The reason for employing a motor movement with a uniform speed to move the cameras is to ascertain the exact duration of a flash or the intervals between the rushes.

The amateur photographer who would take pictures of lightning flashes with a moving camera need have no such device to revolve the camera, as it may be moved by hand, being swung from right to left and back again, each swing lasting about a second and covering an angle of 60 degrees, which is also the angle of the lens. An ordinary magazine camera for all ordinary purposes is the most convenient, on account of the rapidity with which the plates can be changed, this being of great importance, because as a rule the time most favorable for obtaining good pictures is very short, seldom lasting longer than from ten to fifteen minutes.

The best way to hold the camera is to place it close to the body, tilting it somewhat upward so as to get as much of the sky in the picture as possible, and swinging the body from side to side. The time and angle of the swing can be regulated with a little practice so as to be fairly accurate. With the utmost care, however, the element of luck enters into the work to a considerable degree, and the game is one of patience and perseverance.

Official Meteorological Summary, New York, N. Y., November, 1908.

Atmospheric pressure: Highest, 30.45; lowest, 29.49; mean, 30.04. Temperature: Highest, 62; date, 26th; lowest, 27; date, 5th; mean of warmest day, 57; date, 26th; coolest day, 32; date, 15th; mean of maximum for the month, 50.8; mean of minimum, 38.6; absolute mean, 44.7; normal, 43.8; excess compared with mean of 38 years, +0.9. Warmest mean temperature of November, 50, in 1902. Coldest mean, 37, in 1873. Absolute maximum and minimum for this month for 38 years, 74 and 7. Average daily excess since January, 1, +1.6. Precipitation: 0.75; greatest in 24 hours, 0.66; date, 14th and 15th; average of this month for 38 years, 3.43. Deficiency, —2.68. Accumulated deficiency since January 1, —2.39. Greatest precipitation in November, 9.82, in 1889; least, 0.75, in 1908. Wind: Prevailing direction, west; total movement, 9,364 miles; average hourly velocity, 13.0 miles; maximum velocity, 46 miles per hour. Weather: Clear days, 13; partly cloudy, 6; cloudy, 11; on which 0.01 inch or more of precipitation occurred, 3. Frost: Light, 2; killing, 5th. Snow: 0.6. Fog (dense), 10th, 22d, 23d, 24th, 25th.

A $500 Prize for a Simple Explanation of the Fourth Dimension.

A friend of the SCIENTIFIC AMERICAN, who desires to remain unknown, has paid into the hands of the publishers the sum of $500, which is to be awarded as a prize for the best popular explanation of the Fourth Dimension, the object being to set forth in an essay the meaning of the term so that the ordinary lay reader can understand it.

Competitors for the prize must comply with the conditions set forth in the SCIENTIFIC AMERICAN of November 21, 1908.