mathematical discussion. He believes that as larger and larger quantities are taken in our analytical operations, the results differ regularly from ideal accuracy; sometimes the difference continually increases as the quantity taken increases; sometimes the difference increases to a maximum and then decreases again. The proper computation of an atomic weight then, according to Hinrichs, consists not in taking the mean of different observations, made with different weight of materials, but in determining the limit toward which the series converges as the weight taken decreases. A good illustration is given; we cannot determine the weight of a new coin by weighing any number of old coins; every coin is worn and therefore light, and the mean weight of any number whatever is therefore necessarily below the mean weight of new coins. But if we weigh old coins and note the date of each, we may take the mean weights for each year separately. If we examine coins enough, these means when plotted as the ordinates with the years as the abscissas will give us a "fairly regular curve, lowest for the oldest coins, gradually rising toward a limit which they would not quite reach. This higher limit would evidently be the mean weight of the new coin."

This is an intelligible proposition. It seemed to me worth while to examine it, for to this proposition one of the most enthusiastic and most active supporters of Prout's hypothesis, a man not lacking in shrewdness or ability or learning, has intrusted the defense of his favorite belief.

He asserts that an atomic weight as determined by experiment is variable, that it depends on the amount of substance taken for the analysis or other operation, and that it varies in a continuous and regular manner. His proposition is, that an atomic weight as determined by experiment is a function of the weight of substance taken. Is there any evidence in favor of it?

I answer, first: Theory does not afford any evidence for it. Hinrichs deduces this proposition from theory by a discussion which is mathematical in form. Whether the proof is sound need not be considered, for his theory does not attempt to show the order of magnitude of the regular and continuous variations which are affirmed to depend on the weight of substance taken, and to show whether they can be separated from the irregular and discontinuous errors due to accident. We are sure that accidental errors exist; we may concede, for argument, that regular and continuous variations also exist; but this is far from implying that the actual errors in a given set of experiments will be largely or even perceptibly of the latter kind. Theory shows that there is a diurnal tide in the atmosphere; but theory does not show that the differences noted in a series of ten observations of the barometer at different hours of the day will follow the law of the diurnal tide.

But, secondly: Facts do not agree with the proposition. The accidental errors of the most precise experiments yet made are so much greater than any systematic variations, that nothing but accidental variations can be detected. To prove this, let us consider Stas' synthesis of silver nitrate from pure silver. This is one of the most important determinations ever made; Hinrichs has discussed it twice in his volume; he asserts that the ratio of silver nitrate to silver found in each analysis depends on the weight of silver taken, and twice draws curves to show this. I assert, on the contrary, that the errors, which average only 1 part in 40,000, are purely accidental, and that they follow no law. This can be proved by proving that the ratios obtained depend on any other quantities selected by accident just as much as they depend on the weights of silver taken. Hinrichs plots the results of the ten determinations, using for abscissas the weights of silver taken, and so obtains tolerable curves. I plotted the same ten observations, using for abscissas not the weights of silver taken but ten numbers selected by sortes Virgilianae, and get curves quite as tolerable as before; and this I did with ten different sets of abscissas, all selected by pure accident. Now, quantities which depend on any one of eleven sets of abscissas, ten of which are selected by accident, are themselves accidental in their variations, and the variations follow no law. So far as the facts are examined, they give no evidence in favor of Hinrichs' proposition: we have seen that theory is equally chary of her support, and we may safely dismiss the suspicion that any source of systematic error can be detected in deducing atomic weights from the means of good experiments.

(To be continued.)

STRENGTH OF STEEL BALLS.

THE results of tests made at the Rose Polytechnic Institute upon steel balls were reported by Mr. F. W. Harris at the New York meeting of the American Society of Mechanical Engineers. Balls were procured of sizes ranging from $\frac{1}{2}$ to 1 inch in diameter from six manufacturers, and the attempt was at first made to test the balls by crushing between hardened steel plates. Difficulty was experienced, however, in procuring steel so hard that it would not indent under the pressure to which it was subjected in contact with the balls, and the plan was adopted of placing three balls in a row in a special holder, which kept them in line axially. Pressure was then brought to bear upon the two outer balls, eventually crushing the middle one. After this series of tests was completed a steel was found that answered the purpose for testing the balls between flat surfaces and another line of tests was conducted with the balls between two flat plates of this steel. A singular fact is that in the first series nearly all the balls were broken by the formation within the ball of a conical wedge which was gradually forced toward the center of the ball until the latter was split. The base of the cone was approximately circular, with its center at the point at which the crushing force acted. The following table gives average results of the two series of tests. It will be seen that the values in the last horizontal row are higher than in the second row, showing that the balls withstood more when tested between flat plates than when they had the point contact, simply, of the first test:

BREAKING PRESSURE IN POUNDS.						
Diameters.	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1 1/4	1 1/2
Between two balls	2,000	4,000	8,000	15,000	22,000	30,000
Between flat plates	2,000	5,000	12,000	20,000	32,000	40,000

VARIABLE SPEED GEAR.

THE hunt for a good variable speed gear for motor carriages has led to the invention of many ingenious devices, some simple, some complicated, some good, many bad. We have been recently requested to see one in operation which has at any rate the merit of simplicity. Time alone can show if it will be of practical utility. We have the assurance of the inventor that the wear of the parts is not excessive, but as the mechanism depends for its action on a reciprocating and intermittent motion, only a prolonged trial under working conditions can prove that it is sufficiently strong and durable to work for long periods without repair. The general appearance of an experimental gear is shown by Fig. 1. The shaft is not continuous; one end of it is driven at a constant speed, and the

FIG. 1.—NEWMAN'S VARIABLE SPEED GEAR.

other runs at various speeds within the limits of the mechanism. Its rate is regulated by the hand wheel and screw. The internal gear is shown in Fig. 2. It consists of a spur wheel keyed or cut on the extremity of the variable speed shaft, placed centrally in the case. Three wheels mesh with this pinion. Each of these wheels is driven by a roller clutch similar to those now largely used in free-wheel bicycles. A crank pin is fixed as shown in the disk of each clutch. A plate (Fig. 3) carries three limbs, through each of which is a hole into which one of the crank pins is carefully fitted. Inside this plate is an eccentric, of which the throw can be varied by means of a pin working in the spiral slot shown in Fig. 1. The eccentric, it will be observed, is fitted with ball bearings; it is driven by the constant speed shaft and its motion is

FIG. 2.—VARIABLE SPEED GEAR.

transferred to the three-clutch, which it causes to reciprocate more or less as its throw increases or diminishes. When the throw is small, the corresponding partial rotation of the clutch wheel is small, and in consequence the rotation of the variable speed shaft is also small, and vice versa. It must be observed—and the point is of considerable importance—that on account of the arrangement the clutches drive in rotation and that the next one is in before the previous one is out. Were it not for this the blow on the rollers with a heavy load would certainly destroy the mechanism in a short time unless it was made excessively heavy. As it is, no appreciable knock occurs when the gear is running at its highest speed, and if continued use shows that there is not excessive wear of the parts, there should be no trouble in that direction.

FIG. 3.—ECCENTRIC PLATE.

At present the work that Mr. W. H. Newman, of Totteridge Park, Herts, the inventor, is engaged upon, is some means of balancing the eccentric. This is very essential, as in the existing design the vibration at high speed is very apparent. The problem is not an easy one, but Mr. Newman thinks that he will succeed in solving it without great difficulty, and he is, we believe, already engaged on the construction of a new experimental apparatus which shall be free from vibration. Whether the eccentric alone is the cause of vibration remains yet to be seen. It may be found that the action of the clutches coming into gear gives a jerk to the mechanism in spite of the manner in

which they are arranged. It should, by the way, be pointed out that the whole mechanism is entirely enclosed and works in a bath of oil.—Engineer.

GASOLINE MOTORS FOR AUTOMOBILES.

By GEORGE KELLOGG BARRETT.

As many manufacturers as there are of stationary gas and gasoline engines, it seems strange that but few or none of them have turned their attention to the making of gasoline engines suitable for use in automobiles. Doubtless the case would be different if it were known what a ready sale awaits any thoroughly practical motor and if the objects necessary of accomplishment were understood.

As to the former, there is no maker of automobiles who has anything practical to offer who is not flooded with orders. No deliveries are promised within three months of the placing of orders. To add to the stringency, the inability to secure the vulcanite cells for the accumulators of electric vehicles makes those vehicles less active competitors of the gasoline rigs than would otherwise be the case, although the electric is surrounded by so many restrictions in the way of limited area of travel that it is not a really dangerous competitor, except for strictly city use, and even in cities a well constructed gasoline vehicle answers all purposes.

Steam-driven autos are a factor in this country greater than they are beyond the Atlantic, but the objections which apply to the electric also apply—in a much more restricted degree, however—to the steam vehicle. In France, the home of the automobile, steam and electricity are little known for private traction purposes. In England the same condition prevails. At a recent exhibition in London, there were shown but one electric and one steam vehicle, the latter an American one, out of a total of 100 exhibited. While this does not prove that gasoline is to furnish the exclusive motive power of the future, or even the greatest percentage of vehicles, it does prove that it is practical and capable of being made the basis of a lucrative business by many concerns.

That there are so few automobiles seen in America is not due to any lack of demand but to a scarcity of practical vehicles. This scarcity, again, is not due to any lack of capable men working to supply the demand, but to the shortness of the time during which they have been at work, and, no doubt, in many cases, a lack of knowledge concerning the basic principles of the motors on which they are working. Particularly is this noticeable in regard to gasoline motors.

There are numerous difficulties in the way of constructing automobiles, especially steam and gasoline, and the constructor has other problems, quite as difficult of solution, in the building of a thoroughly practical motor. If the constructor were able to buy his motor in an approximately perfect state and then devote his attention to elucidating the other problems, he would be working to far greater advantage. In fact, the other problems are far nearer solution than the one of building a thoroughly practical gasoline engine for this particular work.

Now, those men who are engaged in the manufacture of gas and gasoline engines on a commercial scale, with all the facilities of well equipped shops, with no other problem to divert them from the building of practical motors, and—not the least important advantage—with an intimate acquaintance with the idiosyncrasies of gasoline engines in general, should be able to arrive at the solutions of the problem—there are more than one—in a more rapid and a more economical manner than those who have not these advantages. The only thing necessary is to start with a knowledge of the requirements of gasoline motors as applied to traction purposes. It is the object of this article to outline briefly these requirements.

An engine for a vehicle designed to carry two to four persons should develop at least from four to six horse power, to make it practical under all conditions. Engines of this power will be most in demand for some time to come, if not permanently. Larger sizes will be needed for omnibuses and freight vehicles as well as a few of the more elaborate private conveyances, but the present demand in America is for a motor adapted to private passenger vehicles. Engines of smaller power are suitable for motorcycles—the generic term for two, three, and four-wheeled conveyances built on the lines popularized by cycle building.

Both horizontal and perpendicular engines are used successfully abroad.

Naturally the ideal engine should be economical, but for private traction purposes this is a consideration of minor importance, as the cost of travel is, at the greatest, comparatively small. Other features are more important.

One of them is the desirability of a long period of service without the necessity of replenishing the fuel, which, however, involves the question of fuel economy. The desirability of compactness is so apparent that it seems almost needless to mention it.

Another equally apparent desideratum is light weight, which involves and is inter-dependent upon other desirable features, like constant torque, the absence of large flywheels, the use of multiple cylinders and some provision for cooling without complicated and heavy devices for water circulation. Finally, the engine should provide an exhaust that is as nearly noiseless and odorless as possible.

Taking up the question of weight, there can be set no definite bounds beyond which it is not safe to transgress, as other desirable features might well counterbalance a little weight in excess of what an expert would set down as the maximum allowance. Gasoline motor-vehicles to accommodate two persons have been built as light as 450 pounds. While such light weight is not necessary, it is certainly desirable, for more reasons than one, the most important of which is the many stresses put on the wheels. In a vehicle of this weight, not more than 150 pounds can be devoted to the motor, carbureter, fuel tank and cooling devices. If water cooling is used, it will be seen that there must be light and efficient devices for reducing the temperature of the water after it has reduced the temperature of the cylinder or cylinders, or else the amount of water that must be carried will be too great.

In a one-cylinder engine the weight of the flywheel necessary to maintain anything like constant torque would be too great. Therefore it is desirable to have

more than one cylinder, if for this reason alone. Two have been used successfully; three seem, at present, to be the most practical in actual service; while four, and even a greater number, have been tried with results that have been claimed to be excellent. The use of a multiple number of cylinders makes it easier to provide sufficient cooling without the use of water. It is possible to construct a multiple-cylinder engine in which the flywheel will be an unimportant feature. Of course the construction of such an engine involves expense, but expense will not prevent the general use of a successful engine.

The necessity for eliminating vibration and maintaining lightness is another very cogent reason for using more than one cylinder. Involving several other problems, is the one of constructing an engine that will work well under loads of varying amount and frequent change. Whether this can best be done by running the engine at an approximately constant speed, leaving the matter of the transmission of that speed to the vehicle constructor, or by varying the speed of the engine itself, is a question that is best left to the experimenter to solve. Either expedient will serve. It would seem almost necessary, however, to adjust either the quality or the quantity of the explosive charge in proportion to the amount of work to be done—automatically, of course. Both quality and quantity may be changed, but to keep the quality constant and vary

radiation, the whole arranged in coils. The copper tubes are provided with very thin fins of iron or aluminium, according to the requirements of weight and economy.

The motors of small horse-power or numerous cylinders, however, are provided with no means of cooling other than thin fins for radiation on the outside of the cylinder. Exception may be made in the case of one Frenchman who provided, within the piston, itself, a cooling device, by the aid of simple auxiliary mechanism. It is possible to construct a six horse-power, three-cylinder gasoline engine that will need no cooling device not integral with the cylinders themselves.

The actual speed of the engine itself need cut little figure, as the speed of the vehicle to which it is attached will be regulated in the transmission, unless an attempt be made to regulate the speed of the engine in proportion to the load, in which case the speeds of engine and vehicle are so closely connected as to be inseparable.

The engine should have provision of some sort for starting itself or of being started by the use of light manual power which is operative from the seat of the vehicle.

Finally, an engine that is reversible will prove valuable, as it will relieve the builder of the vehicle of the problem of providing a reverse transmission.

If the features outlined in the foregoing can be ac-

is provided with two "following" head stocks, so that it can be used as two independent lathes, each taking work 30 feet 6 inches long between the centers, each half of the bed being fitted with two saddles and four compound slide rests, while all four saddles can be worked in conjunction when required. The driving headstocks have quadruple gearing, and are driven by variable speed motors. The latter were applied by Messrs. Vickers, Sons & Maxim, after the lathe was in position, all provision for them having been made by Messrs. Beyer, Peacock & Company, in designing the lathe. The main spindles, which are of steel, are 12 inches in diameter, fitted with collar bearings to take the end pressure. The guide screws are each fitted with a clutch arrangement, to enable them to be disengaged from the spindle driving gear, and driven, if desired, by an electric motor, for quickly moving the heavy rests and saddles from one part of the bed to another. The bevel wheel seen at the lower end of the larger worm wheel shaft was provided to enable a motor to be applied when required. Ratchets for giving feed motion are provided to actuate the saddles and rests independently of the guide screw. The lathe is further provided with roller brackets for carrying long and heavy work. The total weight of the lathe is 100 tons.

On account of the great length of the lathe, it was found impossible to get a satisfactory photograph of

ELECTRICALLY-DRIVEN SHAFT LATHE.

the quantity appears to offer the best results as applied to automobiles. The hit-and-miss plan is not feasible.

In this connection, it may be well to say that there appears to be opportunity for great improvements in the way of introducing a measured quantity of liquid gasoline into a measured quantity of air and of having little more than enough of the explosive mixture on hand at any one time than is necessary for the charging of the cylinder at the next inspiration.

Taking up the question of eliminating vibration, that may be accomplished in a number of different ways which will suggest themselves to the experimenter. The use of two opposed cylinders with a flywheel of moderate weight has been found satisfactory. The result, however, can doubtless be better accomplished by the use of three or four cylinders, set in any manner that is found most convenient. It will be well to construct the driving shaft to run parallel to the axles of the vehicle, to do away with the use of bevel gears in transmission.

One highly important consideration is the proper cooling of the engine without the addition of weight of any great amount. This includes the use of little water, if water be used at all. Where water is used, the French, who have arrived at the greatest degree of advancement in the building of gasoline automobiles, utilize water-cooling tubes provided with fins for

complicated with the use of kerosene instead of gasoline, the results will be still more satisfactory.

That it is a difficult task to accomplish all these results is a foregone conclusion, but that it is a task too difficult for American inventive genius, the writer will not admit. We already have the results accomplished by the French and Germans in this line to help us, and it would be an insult to American ingenuity to admit for a moment that we can not excel the foreign designers, once we set ourselves to do so. It is no task to be accomplished in a day, but, when it is accomplished, the financial results will be more than sufficient to pay for long and studious work.—Modern Machinery.

A BIG SHAFT LATHE.

THE lathe illustrated herewith was recently made by Messrs. Beyer, Peacock & Company, Manchester, for Messrs. Vickers, Sons & Maxim's works at Sheffield. It has driving headstocks and face-plates at both ends. The latter are 6 feet 3½ inches in diameter, and the bed is 90 feet long, giving a clear length of 75 feet 6 inches between the main centers. It was specially designed for heavy work, such as guns, propeller-shafts, and the like, and is fitted with the necessary appliances for sliding, surfacing, and screw-cutting. The jaw chucks can take work 5 feet 7½ inches in diameter. It

more than a portion showing one rest. The other rest and headstock are precisely similar to those shown.

We may add that tests made by Messrs. Vickers to ascertain the E. H. P. expended in driving one of the headstocks under the conditions named below gave the following results: *a.* Running "light" with a 23-ton forging, slowest lathe gear and fastest motor gear, 450 revolutions, 0.6 horse power. *b.* Boring a gun carriage, weight 2½ tons, cut ¾ inch, by 0.5 inch feed, 1.2 horse power. *c.* Same piece of work, parting cut 2¼ inches wide, by 0.04 inch feed, 6.5 horse power. *d.* Rough turning a gun tube, 23 tons weight, four tools roughing, each cut ¾ inch, by ¼ inch feed, two tools on 29-inch diameter, and two on 19-inch diameter, the lathe gear and speed being the same as in *a*, 107 horse power.—The Engineer.

LORD RAYLEIGH ON FLIGHT.

At a meeting of the Royal Institution, Lord Rayleigh delivered a most interesting discourse on the above subject. He pointed out that the main problem of the flying machine was the problem of the aeroplane. The action of the wind on the plane could be experimented with up to a certain extent by means of kites, but these kites were always anchored to the ground, and as soon as this anchoring was taken away, the problem becomes much more difficult. Lord Rayleigh proceeded