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H. C. H. SHENTON (VICE-PRESIDENT), IN THE CHAIR.

THE NECESSITY FOR SAFER, QUICKER, AND CHEAPER RAILWAYS; WITH SOME PROPOSALS THEREFOR.

By C. REGINALD ENOCK, F.R.G.S.

[MEMBER.]

IT is the purpose of this paper to inquire how far the present system of railway construction and working is keeping pace with the requirements of the age; and whether radical improvements are not both necessary and possible.

For all main purposes of passenger and freight movement the railway holds its own. We have perfected the motor car and developed the flying machine, but neither of these can replace the particular function of the railway. But, notwithstanding the great improvements that have taken place in railway science since the first locomotive ran, the railway is still too slow, too insecure, and too costly. Either we have reached the limits of its capacity, or else engineers are displaying a lack of ingenuity in its development. We are still killing and maiming large numbers of people on the world's railways; we are still unable to make such profits upon operation as will ensure railway operators a sufficient wage, passengers and freight a sufficiently low fare, and capital at the same time a sufficient dividend; and we are still halting in opening up the waste places of the earth, by reason of heavy cost of construction. All this may seem to be in the nature of an indictment, but if so it may serve to arouse discussion and stimulate thought.

About seventy years ago a line of iron rails was laid down, and a number of slightly adapted stage coaches strung together, and drawn by what was essentially the steam locomotive of to-day,* were caused to travel thereover. It was one of the greatest epochal achievements ever made; but to-day we are still travelling in what are practically a string of more or less insecure stage coaches, perched upon those same lines, drawn by a similar locomotive—a modern train, which can do little more than run along the bottoms of valleys, and that at high cost and with danger to its occupants. Such statements may appear exaggerated to the suburban railway traveller of Great Britain, and whilst, of course, they are meant to give point to argument, a survey of the condition of the world's railway systems will show that they are not

* The "Rocket" (1830) possessed the three elements of efficiency of the modern locomotive of water-surrounded fire-box, multitubular flue in boiler, and blast pipe, and direct connection of cylinders with driving-wheels.—ARTICLE IN THE "ENCYCLOPÆDIA BRITANNICA." (Eleventh Edit.)

unjustifiable. The railway has been, perhaps, the greatest mechanical friend of mankind, but that will not prevent our gratitude taking the form of a lively sense of favours to come.

Security.

The first element to be considered is that of personal security, notwithstanding that in railway construction in new countries this has taken a place secondary to that of development. It is a sort of popular saying in England that a railway carriage is one of the safest places in the world, and, relatively, this is not untrue. A less appreciative simile was that famous one of Ruskin, who spoke of "a carriage full of damned souls on the ridges of their own graves." Both statistics and general considerations must be taken into account, however, in the present argument. The following table shows the number of persons killed and injured from all causes connected with railway operation in the United Kingdom and the United States in the year 1907* :—

	Passengers.		Employees.		Other Persons.		Total.
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	
United Kingdom ..	125	3,502	509	21,514	577	959	27,186
United States	610	13,041	4,534	87,644	6,695	10,331	122,865
					Grand Total ..		150,051

Thus, in these two countries, representing the extremes in railway matters, we have the heavy total of 150,051 persons killed and injured in one year.

These figures, of course, require examination in order to arrive at results which can be put down to accidents whose fault lies with actual railway science, for the greater part of such disasters are due to outside causes. Thus, for the year given, in the United Kingdom, only 18 passengers were killed and 534 injured due to actual disaster to trains in which they were travelling, whilst in 1908 no passengers were killed under that heading and only 283 injured, out of a total of 1,128 killed and 24,485 injured of all persons from all causes in that year.

Furthermore, accidents appear small when taken in comparison with the number of passengers carried, and for the year 1907 the ratio of passengers killed was 1 in 83,000,000, and of injured 1 in 3,000,000.

The employees, however, are far less immune, and as engineers we are equally concerned therewith. It has been calculated that

* Compiled from statistics in the "Encyclopædia Britannica."

in Great Britain one railway servant is killed every 16 hours, the shunters accounting for the greatest proportion. In the United States the slaughter is far more appalling.

To turn from effect to cause, the following were the principal causes of accidents in the United Kingdom in the year 1907 :—

Collisions (of all kinds)	405	accidents.
Derailments	589	"
Trains running through gates at level crossings, etc.	364	"
Fires in trains	170	"
Failure of couplings	2,440	"
Broken rails	289	"

Including other causes of 24 enumerated varieties, the number of recorded accidents was 4,890, due to matters of rolling stock, vehicles, and permanent way.

Whilst, if we regard these matters from the point of view of statistics or percentages, we might feel called upon to agree with the "Encyclopædia Britannica" that railway accidents are already near their "irreducible minimum"* ; on the other hand we should maintain that so considerable a destruction of life and property ought to call forth greater effort and ingenuity in its prevention. We are constantly shocked by the occurrence of railway disasters, and engineers must refuse to take up a complacent attitude. It must often occur to the engineer when he beholds a heavy express train in motion, marks it rattle over points and crossings, sweep around curves, and brush within a few inches of platforms, that we are playing with mighty forces and are often separated only by a hair's breadth from disaster. This feeling is intensified when our work has taken us to where enormously heavy trains stagger across the high, insecure viaducts of the American West. It will occur to us that heavy locomotives at high speeds, on sharp curves, keep on the line more out of the kindness of Providence than by reason of mechanical laws. As we must contravene natural law by enclosing ourselves in fragile structures, to be hurled through space, we must see to it that nature takes the least possible toll from the contravention. Are we doing this ?

The determining factors in security may be described as two—the personal element and the equipment. In the United Kingdom we may congratulate ourselves on the careful and humane methods and excellent discipline in railway operation which are daily translated into terms of saving of life and property. In the United States it is the personal element that is largely to blame for the high ratio of loss and injury. Whilst the Americans are certainly the cleverest and most enterprising of railway builders, and have taught the world great things in railway location, their

* See "Railways" in that publication.

habit of taking chances, haste, lack of discipline, and subservience to money-getting bring up their sinister statistics to a high figure. A certain callous spirit of independence in the American character daily translates itself into terms of loss of human life and limb. It is scarcely a figure of speech to say that railway disasters in America began at the moment of throwing overboard the Boston tea-chests!* Of course, it is to be recollected that the enormous stretches of desert country crossed are factors in producing accidents, and to the credit of Americans be it said that their railways are the most audacious and colossal examples of the road-building art of mankind, both by the methods and rapidity with which they have been built and the method under which they were financed, and they deserve our admiration in this respect.

Thus it may be said that in the United States both the personal element and the equipment require improvement, whilst in the United Kingdom it is to a general advance, mainly concerning equipment, that we must look for improvement.

Remedies and Improvement.

These considerations bring us to the question of what improvement can be suggested in the permanent way and rolling stock of railways. A reference to the list of accident causes shows how large an item is furnished by collisions and derailments, and these undoubtedly give rise to the greatest loss of life and injury among passengers. Collisions occur on the best regulated lines; and until we are in a position to change the present system, whereby express, local, and goods trains use the same tracks, they must be expected to occur. Pending this, however, are there no points of improvement to be aimed at in locomotives and carriages?

Carriages.—If we examine a railway carriage intelligently we shall perceive that its structure scarcely fulfils the conditions for a vehicle designed to hurtle through space with a living freight at a mile a minute perhaps, and subject to the condition of being brought up sharply, as in a collision. A blow given at one end of this relatively flimsy structure reduces it to matchwood, and its occupants equally to dissolution in extreme cases. The reason of this faulty construction is evident. It is presupposed that a railway carriage will not have to sustain shock. As a matter of fact, a railway carriage has never got beyond the stage-coach period of evolution in this respect. But the question now arises if it should not be designed to resist destruction in collision. It is a common occurrence that the front or rear coaches of trains

* "Will nothing interfere with the American railroad's beneficent work of reducing its patrons to pulp? Cannot American railway passengers be safeguarded as in England?" the *New York World* asked recently.

are telescoped, and this is the most frequent cause of loss of life and limb, which would undoubtedly be heavier were it not that passengers distrust the front coaches, and prefer to occupy the centre or rear of the train. It is plain that some improvement is necessary here, that the ordinary railway carriage does not offer sufficient protection to its passengers. It is conceivable that a carriage could be so constructed that under the shock of collision passengers, although they might be shaken and injured, would at least not be maimed, mutilated, and burnt to death, as frequently happens at present, even on the best railways.

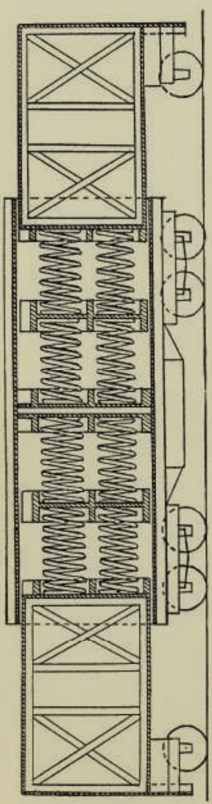
Shock-resisting Carriages.

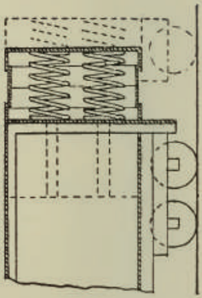
The proposal is here advanced that telescopic and crushing action in collision should be anticipated and provided for, and the author ventures to bring forward a design for a structure of such a nature, for criticism (see next page).

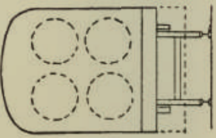
This calls for a carriage of three compartments, the two end ones, normally used as guards' or luggage vans, capable of sliding or telescoping into the central compartment, which contains a series of powerful coil springs, aggregating twenty or more feet in length, whose thrust would be given and taken by steel plates forming the ends of the compartments. This would give, in effect, a buffer resistance of the whole area of cross-section of the train plus the length of spring. The compartments would be formed of steel framing so strong as to be practically indestructible, and covered at the outer ends with armour plates reaching from the top of the carriage down to within a foot or so of the rails, whose function it would be to prevent the passage of wreckage, fire or steam. This special carriage would be placed at the front and rear of express trains, or, indeed, of all passenger trains, and in the centre also in the case of very long trains. An adaptation of the springs and armour plate could be used for every sleeping, dining or other coach if necessary. It is argued that the destruction of front and rear coaches in collision would be obviated, and the shock greatly minimised. The author has submitted this design to six of the principal railway companies of Great Britain, but none of them has shown any disposition to adopt it. This may be accounted for either by inherent defect in the plan, or by the traditional conservative attitude of English railway companies. We constantly forget the principle embodied in the classic reply that it might turn out " awkward for the cow "—that is to say, to refrain from condemnation without experiment, an omission to which our conservatism is somewhat prone.

The Lesson of Accidents.

Whatever system, however, might be adopted, the fact remains that greater security and strength in carriages is desirable. The details of accidents are liable to be forgotten, but we have







only to go back a few months to recall such. On Christmas Eve last a Scotch express was wrecked and twelve passengers were burned to death in the wreckage. In the official report the blame was placed on the signalman for having forgotten the two light engines left on the line, into which the train ran, and upon the drivers of the light engines for not sounding their whistles when kept waiting, and remedies were suggested against telescoping. Another recent accident occurred on June 24th, when an excursion train dashed at midnight into a siding, and was wrecked at the stop blocks. Due to the fact that the two front coaches were empty and locked, there were only eleven persons injured. In August a Birmingham express train crashed into a stock train, and 35 persons were injured. The first coach contained no passengers, which accounts for there having been no deaths.

In the United States express trains consist of heavy Pullman cars mainly, with lighter day coaches in front. These Pullman cars are exceedingly solidly constructed. "Always ride in a Pullman," said a railway inspector in the United States to the author, "in a collision they go through everything else," and, indeed, the author has witnessed the truth of the statement, where the front cars were telescoped and destroyed by the following Pullmans, which themselves remained intact.

The moral of many accidents is clear : we require for passenger coaches a different type of construction, and in train movement greater care and observation. Upon this latter point some suggestions are now offered.

Observation by Engine Drivers.

There is one matter in connection with the safe march of a train worthy of greater consideration and development. This is the matter of vigilance en route. A steamship has various officials whose sole duty it is to be on the look-out. On a locomotive the pilot, helmsman, chief engineer, and forward watch are all rolled into one in the form of the engine-driver, plus his stoker. The conditions, of course, are far from being analogous, but even then facts will seem to show that under present conditions the safety of a moving train is not under sufficient vigilance. The suggestion is here brought forward that locomotives, or at least the locomotives of express trains, should carry a specially trained observer in a specially constructed vantage-point in the front of the engine. Such an official might be, as regards technical knowledge and education, superior to the ordinary engine driver, with natural and trained powers of observation and concentration, and his eyes and ears would be constantly open for evidences of anything wrong ; and by an intelligent anticipation of events he would strive to avert accidents. Points, sidings, signals would be carefully scanned as they were approached, possibly with the aid of binoculars in the daytime and searchlight by night. Obstacles on the permanent way might be detected or suspected by this close vigilance and power of observation, a faculty which too much of mere mechanics tends to minimise. The author ventures to think, after considerable experience with natives in undeveloped lands, that the natural or acquired power of suspicion and observation such as they display is not sufficiently cultivated in more civilised life, and that trained faculties of "scouting" of this nature would tend to avert accidents. The cost of added salaries would, of course, have to be considered, but the averting of accidents would more than cover such. Be it, however, as it may, a study of the causes of accidents shows that in many cases they might have been avoided by a more vigilant look-out from the engine. Here, also, we suffer from the stage-coach evolution at present.

Further matters connected with security are those of the high centre of gravity of rolling stock and curvature of the line, which are referred to elsewhere.

SPEED.

We now come to considerations of speed, and it is here contended that we are not able to travel fast enough for the requirements of the age. The "Rocket" ran at 12 miles an hour. The author lives at a little more than 12 miles from London, and it takes him nearly an hour to get in by rail. This, of course, is not a fair analogy of speed, as local times are largely due to stoppages and changing. Nevertheless, even with what may be termed local express service, places 25 miles from London generally take an hour to reach, and to that must be added 10 to 20 minutes on the tube railways to reach the City or West End. Local transport is much bound up with social advancement. If we are to continue congregating in cities by day and leaving them at night we shall inevitably require transport which will take us farther away in much less time than at present. Of course it is highly probable that, as time goes on, conditions of decentralisation will bring about changes in railway travel and that the great ebb and flow to and from cities will cease to some extent. Already considerations of space are causing workers to go farther afield, and no doubt a time will come when the industries will follow the workers, and it may be said the sooner that takes place the better for social advancement. At present, however, we require greater local speed.

As for long-distance traffic, this is much slower than we might legitimately hope for. To reach distant points takes us too long. Following are some examples of daily railway travel taken from the time tables.

London to Edinburgh, 400 miles: Out of twelve trains daily there and back, on the L. & N.W. Railway, the average time is

9 h. 15 m., or an average of about 43 miles an hour. The quickest occupies 8 h., or 50 miles an hour, and the slowest 12 h. 18 m.

London to Manchester by same line, 183½ miles, and the time average of 31 trains is 4 h. 18 m., or about 43 miles an hour. The fastest takes 3 h. 30 m., or about 52 miles an hour, and the slowest 5 h. 55 m.

London to Plymouth by G.W. Railway, 226½ miles, with a time average of 5 h. 42 m., or about 40 miles an hour; the quickest being 4 h. 7 m., or about 55 miles an hour, and the slowest 8 hours.

London to Portsmouth, a distance of 73 miles, takes 2 h. by the quickest train; whilst from London to Brighton, 51 miles, the shortest time is about 1 hour.

Of course, these times are exceeded for short stretches in long runs, and the author has timed trains between Paddington and Exeter, on the Great Western Railway, at the rate of 4 miles in 3 m., but for all intents and purposes 42 to 44 miles an hour between our great towns is all that railway science can give us—speeds, moreover, that were attained many years ago.

In the United States the average speeds are still lower. It is true that the "Twentieth Century Limited," a famous express on the New York Central Railroad, covers the 1,000 miles between New York and Chicago in 18 hours, an average of slightly over 55 miles an hour, claimed as "the world's fastest and longest non-stop run." Also the other splendidly built and well equipped railways from the Atlantic seaboard to the Mississippi Valley and Great Lakes reach speeds not inferior to those of British lines. But in the West speeds are much lower, and probably the average is not more than 25 miles an hour, even where stations are far apart.

In general terms it may be concluded that the limit of practicable speed on steam railways has been reached under the present system, and if greater velocity is to be attained it will be by radical changes in permanent way and rolling stock. That conditions of increased speed are necessary will scarcely be questioned.

Cheapness and Economy.

To come now to the matter of greater cheapness and economy, two factors stand out—the great cost of building railways and the relatively high cost of travelling and freight haulage. If these matters could be reduced, both the business and social welfare and intercourse of the world and the unexploited parts of the globe would be capable of far more intensive development.

It cannot be said, however, that these high costs are the result of exorbitant profits made by railway builders or by railway shareholders, or of high wages to railway workers. Taking the year 1907, the return on the paid-up capital of all British railways, amounting to £1,310 million, was 3·32 %; and that of the United States $16,082 million, 5·1%.

In 1888 the British dividend was 4%, and in the United States 3·25%, showing in the one case a decrease and in the other an increase to the present time.

For last year, 1910, the dividend on the paid-up capital of all British railways, amounting to £1,318 millions, was 3·48%.

In the United States the railway workers are paid far better than those in Britain, even when the added cost of living in America is taken into consideration. Nevertheless, the same conditions will be encountered sooner or later in America.

As regards high cost of construction or heavy capitalisation, this has been due in large part in Great Britain to matters of land purchase. It is one of the penalties we pay for our system of private land monopoly. In the United States, Canada, and Mexico vast areas of land were often ceded by Governments to railway companies as a subsidy for building, and in South America are still so ceded. The actual cost of construction of many of the well built railways in the Eastern part of the United States does not differ greatly from that of British lines. Yet the total cost in the one country is less than a third of that in the other, due to the item of land. The following calculation, for the year 1908, is made on a single-track-mile basis, that is, disregarding sidings, and shows the amount of paid-up capital per mile :—

	Single Track Mileage.	Paid-up Capital Per Mile.
		£
United Kingdom	39,316	33,333
United States	254,192	10,372

The present prospects are that construction and travel and haulage, rather than becoming cheaper, are likely, under the present system, to be dearer. As regards construction, the increased costs of wages and material are those which will tell. Whether the price of steel will be greater or less remains to be seen, but certain it is that the world's supply of timber is becoming depleted, and that cost has risen greatly and must still rise. This is due both to improvident waste and to other causes. In America forests have been cleared away, both for timber and fuel, and vast areas of stumps greet the traveller's eyes, whilst re-planting has been neglected—as indeed afforestation in Britain is neglected.

As regards wages, and consequently the cost of operation, the workers in Great Britain are not unreasonably demanding an increase, and higher rates may follow. The average pay of railway workers in the United Kingdom is stated to be only 17s. or 18s., and it is a matter for surprise, not that a demand for higher pay should now be made, but that the demand should be made only now. The weekly wage of 100,000 railwaymen is £1 and under, and they work not less than 65 hours a week, and in many cases 72 hours. The matter of long hours, at least, concerns the safety of the travelling public, apart from humane considerations. No system of industrial civilisation can endure which cannot better provide for its workers. The author submits that it is time to consider whether we are not suffering from a "great illusion" in paying labour of all kinds as little as possible, instead of as much as possible. That higher wages would ultimately result in higher profits all round, the balance adjusting itself at its natural fountain head of a more intensive and extended exploitation and development of the resources of the globe. This, however, is not within the scope of this paper.* Recent events, the matter of railway strikes, have but accentuated what all students of our social system have long been aware of, that the well-being of society is dependent upon the well-being of the workers. Indeed, the indispensable part played in modern life by the railway has once more been brought home to the community. If we can cheapen the cost of its working we shall be able to pay a better wage, whilst still retaining a fair dividend for capital. We shall do more—we shall cheapen the cost of food and raw material. Under present conditions it is the cost of transport, not of production, of food products especially, which renders our food so increasingly dear. The author has seen loads of the finest fruit cast into the sea or left rotting in the fields in Western America, because the cost of its transport was prohibitive; whilst in Great Britain fruit is practically unattainable for the poorer classes for a great part of the year.

Another element to be considered under the heading of economy is that of half-empty trains. Any observer will note during the greater part of the day, on any railway, long trains with a handful of passengers scattered through them, and many empty coaches. Yet no effort seems to be made for swifter individual motor-carriages at the slack hours. Possibly there are reasons for it known to traffic managers; but it looks extremely wasteful to the engineer.

TOPOGRAPHICAL CONSIDERATIONS.

It is largely to topographical considerations that we shall have to turn for relief. At present we are overcome by topography rather than overcoming it. If it were possible to dominate steep gradients easily, a great part of the cost of construction would

* The author debated this point in a paper before the British Association at the last meeting of that body.

be avoided, curvature largely eliminated, and alignment simplified, with consequent diminution in friction, driving power, wear and tear, and danger of derailment and other accidents, as well as the shortening of distances. In brief, if it were possible to go over hills as well as round them much would be gained. Even in our railways over the comparatively level surface of Great Britain the enormous work and cost involved in cuttings and embankments is one of the most notable features of construction. To be able to haul a load up a gradient of 1, 2, or 5% even (the maximum at present) is a very inadequate means of traversing the surface of this indented globe. When we observe the ease with which a motor car surmounts a steep road we shall decline to think that greater capacities for our railways are impossible.

As to more mountainous countries, any consideration of the slow development of these, due to lack of railway transport consequent upon the present heavy cost of construction and the inability of trains to ascend steep gradients, will no doubt cause the observer to ask if it is not possible to evolve some other system. The extraordinary cost and difficulty of getting up mountains with railways depending upon simple adhesion is shown on every continent. The west coast of North and South America, for example, is cut off from the interior of those continents by the Andes and other mountain chains for more than 10,000 miles, with few passes under elevations of 7,000ft. for the northern continent and 12,000ft. for the southern. Typical examples of these difficulties are shown in the famous " loop " on the Denver and Rio Grande Railroad, over the Rocky Mountains, and the remarkable series of zig-zags on the Oroya Railway, reaching an elevation above sea level of 15,660ft., in the Andes of Peru.* Small haul, great fuel consumption, and high cost of maintenance are naturally features of such lines, added to the huge first cost.

In some of these mountain systems almost impossible degrees of curvature have to be resorted to, such as reduce both speed and safety to a minimum, and this feature will have to be eliminated in the future. It is to be recollected that mountainous countries are often extremely rich in minerals. In Peru and South America generally, in the Andean region, enormous mineral wealth lies unexploited from lack of means of transport—coal, copper, silver, gold, and all else ; whilst the wealth of the great basin of the Amazon in agricultural and forestal possibilities lies almost untouched for the same reason. Analogous conditions occur in many parts of the world. France and Spain are cut off from each other ; huge parts of India and Tibet are unexploited, and so forth.

How are we to get up these high places ? Will flying help us ? Not yet, probably, although in this connection the author has ventured to speculate somewhat, later on. Perhaps the future

* See the author's book, " The Great Pacific Coast."

will evolve for us some new possibilities of power in mountainous regions. Some difference of potential due to great elevations above sea level may become available. In the high regions of the Andes and elsewhere we have sometimes only half an atmosphere weighing upon us ; whilst the presence of electricity in the atmosphere is very noticeable to the traveller. Be it, however, as it may, we require easier access to mountainous regions, and it is time that engineers should apply themselves to the subject with greater exercise of imagination and ingenuity. Rack railways and cable railways do not appear to solve the problem. Possibly electricity will show itself of greater utility. Mountainous regions generally contain water power, and hydro-electric energy is capable of much development there. But withal simplicity must underlie all and any new railway system. The admirable feature of steam railways is their simplicity. There is no costly power house nor electric currents to be cut off, with consequent paralysis. The locomotive is a law unto itself, a self-contained unit, generating, under simple principles, its own power as it goes along, from the commonplace materials of coal and water.

There is, of course, a philosophical point of view of the matter of freight haulage, just as there is in the matter of local travel, as mentioned before. Looked at in this light, probably we are doing a great deal of useless hauling of food and articles about the earth's surface—things which might be used or consumed in their place of origin, or produced in the places to which they are carried. It is, in this sense, reminiscent of the activity of ants, which climb great obstacles with heavy loads in an apparently reasonless manner. Thus, Great Britain consumes great quantities of foods brought in over mountains and seas which she could produce on the spot to a large extent, and sends abroad great quantities of manufactured articles which might be, and doubtless will be soon, made on the spot by their present purchasers. There is little doubt that a large part of freight traffic on railways consists in " taking coals to Newcastle," and this is not likely to endure very long. It is, however, " a condition and not a theory that confronts us," and it is time for cheaper and swifter transport.

New Types of Railways.

If we are to attain to greater speed, security, and cheapness in our railways it can scarcely be doubted that some radical change in construction and form of permanent way and rolling stock must evolve. We have certainly not reached the limit of mechanical speed, as shown in their respective fields by motor cars, torpedo boats, hydroplanes, and flying machines, but we have reached the limit on the ordinary steam railroad. It is time at least to experiment upon new railway types. Upon what lines is it possible that such might evolve? The question is philosophical as well as mechanical, and imagination must play its part too.

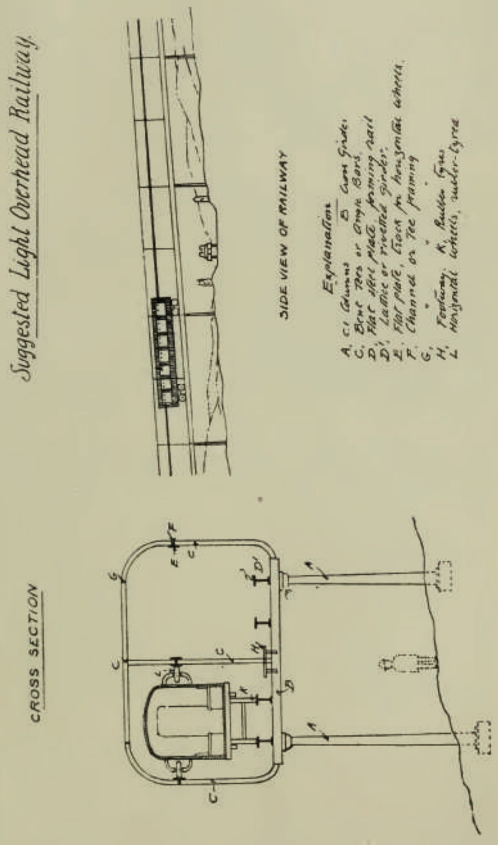
It is quite possible that lightness and mobility rather than heaviness and solidity will be the elements to be considered. So far we have cultivated the security and utility that come with *weight*: but it may be that security and utility with *lightness* will furnish a key to the problem. We may discover that the hurling of heavy masses of iron and timber through space, as practised with our present type of rolling stock, is unscientific.

Points which are strongly held up to our consideration in observing an ordinary railway are the cost of land over which it runs and the considerable area occupied and rendered useless thereby for other purposes: as also, the great amount of work involved in cuttings and embankments, the matters of ballast, drainage, culverts, bridges, tunnels, etc., the ponderous weight of rail and material in the permanent way; and great weight of the rolling stock; and the imagination endeavours to construct for itself some system free from these attributes. But what form could it take?

In the author's mind it takes the form of light, rapid, individual vehicles, rather than long, heavy trains, running at frequent intervals upon a light structure of uninterrupted line under conditions where collision and derailment would be impossible, rather than upon a ponderous and interrupted route; vehicles flashing from city to city at double or treble the present speeds, and at a tithe of the present cost. Such a vision, of course, requires to be brought into terms of cold practicability.

Light Overhead Railways.

It is possible that a system involving light overhead railways is worthy of consideration and experiment. Not, however, of the ponderous and unsightly type of structure which defaces the side streets of New York, but a structure in which lightness, appearance, and low cost were the elements for success. Such a line may be conceived as running across hills and valleys, consisting of little beyond light trussed steel beams carried on columns set in the ground at such a height as to clear ordinary obstacles of roads, hedges, etc.; and of a character such as would leave the ground beneath it free for agricultural purposes. Single light vehicles would run upon this structure at high rates of speed, and their stability upon the line against lateral movement would be provided for possibly by side wheels set horizontally above the centre of gravity, revolving against side rails. Thus such vehicles could not run off the line. The use of rubber tyres or some other method of increasing adhesion would enable these motor carriages to overcome the very steep gradients which the proposed system of crossing hill and valley in a more or less direct


Suggested Light Overhead Railway.
CROSS SECTION
SIDE VIEW OF RAILWAY
Explanation
A, C.I. Columns B Cross Girders
C, Bent Tees or Angle Bars,
D, Flat steel plate, forming rail
D', Lattice or rivetted girders,
E, Flat plate, Block for horizontal wheels,
F, Channel or Tee framing
H, Footway K, Rubber Tyres
L Horizontal wheels, rubber-tyred

line would involve. Instead of rails, plates might be used, and non-flanged wheels. Such structures would be, in effect, a species of elevated motor-roads, with the matter of steering eliminated. If such a system were found practicable it is easy to see how great would be the economy over the present railway, especially in the matter of earth-work, fencing, tunnels, bridges, telegraph posts, drainage, etc., all of which would be eliminated, and the occupying of land, which last item in a country such as Great Britain must become of growing importance. That our future railways must always cost us £33,333 a mile the author refuses to believe.

Rail and Airplane.

Following out this line of thought, and giving play to the imagination, experiment might be made upon the plan of a combination of rail and aeroplane—a semi-flying vehicle using both earth or rather rail and air as supporting and even propelling elements. There does not appear to be any existing example of such a means of locomotion at present, even in nature, unless it be the ostrich. Under such a system it is conceivable that the air-planes forming part of the vehicle would lift it very slightly off the rails, the driving power then being derived from the side wheels before mentioned, working against the side lines, which might take the form of thin bars or plates, so allowing for a small rise and fall of the vehicle. These and the other wheels would be rubber-tyred. A similar rail overhead might be necessary to keep the vehicle down, and thus the carriage would become a species of enclosed flying machine. Whilst such a plan might seem to involve contradictions it must, nevertheless, be recollected that the action of aeroplanes at great speeds of 100 or 200 miles an hour might reveal valuable conditions hitherto unknown. It might be found in practice that the vehicle would be kept constantly lifted off the bottom rails, and that the function of driving would be performed by the side and overhead wheels. Be it as it may, the matter is worthy of scientific investigation. If such a system were found practicable, the problem of mountain railways, among others, would be nearer solution. The monorail and the gyroscope might have their adaptations in such a scheme.

National Experiment.

If anything practical is to be accomplished without interminable waiting for the ordinary slow methods of first rendering improvements commercially paying, experiment must be carried out for the demonstration of any schemes or systems likely to prove useful. At present there are no opportunities for experiment. They would be too costly for the private individual or company. For example, in order to prove a new type of railway a stretch of land and considerable funds would be required. The author ventures to suggest that a combination of our great railway companies, aided possibly by a grant from a Government development fund, might be made, and a right of way on Crown lands, or in such a place as Dartmoor or the Yorkshire moors, be secured and a staff of engineers retained for purposes of such experimental schemes. It is not too much to think that the cost would be covered by the discovery or development of something new and practicable. Hill-climbing methods, the effect of collisions, and so forth could be studied. Especially could the effect of very high rates of speed be studied. Part of the work might be that of giving scope to the ideas of poor inventors in a more generous spirit than at present exists. If we decided to "let Geordie have a try" now and then we might evolve a new Stephenson! At present we are too niggardly and unimaginative. Inventors seem to incur penalties rather than rewards under existing systems.

It is scarcely necessary to reiterate the importance of railways in the daily life of all civilised nations, especially in view of recent disorganisations. But it is time that engineers and general managers came to the rescue of society by devising means for safer, quicker and cheaper transport; and we believe that their ingenuity will not fail to keep pace with the requirements of this rapid age.

Discussion.

The Chairman proposed a vote of thanks to Mr. Enock for his paper, which certainly dealt with railway matters from the point of view of the idealist, but was, he thought, the more valuable for that very reason.

Engineers were always ready to discuss the practical details of their work, but they were not, as a rule, so ready to look at things from an absolutely outside standpoint. Mr. Enock looked at railway systems very much in the manner in which a visitor from another planet might look at them, and criticised without consideration of expediency or of what was likely to be immediately profitable. He had told them what engineers should strive for, and had endeavoured to start a practical discussion. Every pioneer had great difficulty in making people take his ideals seriously, and the higher the ideals the less likely were they to receive serious attention. Mr. Enock raised points which deserved the serious attention of railway engineers. It was profitable at times to review matters from such a standpoint as that adopted by the author, and the Society might very properly enter into such a discussion.

The average engineer was apt to treat comments such as the author had made with tolerant, self-satisfied amusement. There was even sometimes a feeling of antagonism against the person who had the hardihood to demonstrate that we were living in a world which was still far from perfect, and that, hard as we had worked, we must aim yet higher if we wished to advance. Of course, it was not to be supposed that the author could deal practically with the matter in a short paper, but he had made a few suggestions in order to lead to discussion; neither was it likely that at a meeting like the present one the question of how we were to provide safer, quicker and cheaper railways would be settled, or that anyone would be able to point to anything which would lead to an immediate advance; but, on the other hand, it was to be hoped that a discussion would be started which would begin a new consideration of this subject.

There was no doubt that the higher the ideal the better would be the ultimate achievement; an ideal could not be too high. There was no doubt that at some future date many of the shortcomings pointed out in the paper would be set right, but they could only be set right by careful consideration and serious discussion. He (the Chairman) was not a railway engineer, and therefore, would not touch the practical side of the question. He hoped that there would be a good discussion of practical matters on the part of the railway engineers present.

The following communication from **Mr. F. G. Bloyd** (President) was read by the Secretary:—

I am pleased that during my year of office Mr. Enock has brought forward a paper dealing with the important question of railway construction and working, as not only is the subject one that appeals to me personally, but it is also one which should open out a thoroughly good discussion, seeing that the points covered are set forth broadly, and not in the highly technical manner usually found in papers read before a professional Society.

With the statement made by the author that "For all main "purposes of passenger and freight movement, the railway holds "its own," I am quite in accord, and although I disagree with his subsequent observation, that "the railway is still too slow, too costly and too insecure," and that "Either the limits of its capacity have been reached, or else engineers are displaying a lack of ingenuity in its development"—yet I would not ask for the entire deletion of the words, as the better side of a public service is often only discovered after it has first been soundly denounced.

It must be remembered that railway construction has from its inception been burdened by stringent and in some cases rather unfair legislation, and many desired improvements in working have been much curtailed owing to the narrowness of the gauge adopted by George Stephenson, and the restricted size of many of the large works planned by the earlier engineers.

Moreover, it must not be urged that present-day managers or engineers are lacking in ingenuity, or are blind to the need of many improvements, for under modern conditions the hands of the best intentioned company are frequently tied owing to the exorbitant demands made by councils, local authorities or landowners, whenever any new works are proposed, and I would repeat the plea contained in the address that I had the honour of reading before the Society in February last, that until the regulations can be relaxed to meet the special circumstances that often obtain, and the more cordial assistance—not merely the sympathy—of local authorities and landowners can be enlisted, there will be but small inducement to companies to foster new schemes, or to capitalists to find money for them.

Railways must be regarded as public institutions, and with a more complete chain of co-operation between the Government, local authorities and the public themselves, on the one side, and the companies on the other, there should be little, if any, ground for doubt as to their future success in working.

Mr. W. M. Acworth said that he was not an engineer, and was only, in a very indirect way, a railway man. The Chairman had said that they could not pitch ideals too high. That was all right in theory, but he was not sure whether it was always profitable to attempt to translate that theory into practice.

This was the feeling that he had when he read Mr. Enock's proposal for carrying what might be called " collision buffers " on the train itself, in addition to having, as was frequently seen at big terminal stations, hydraulic buffers at the dead ends. He rather doubted, in the first place, whether the guards would consent to ride, as the author suggested, in the collapsible compartments prepared for their reception. Further, he did not think that the game was worth the candle. He did not know what the compartments would weigh with armour-plate and springs and so on, but it would mean a good many tons at each end of the train. Let them assume, for the sake of argument, that coal alone cost on an average 5d. a mile for a load of 200 tons. If they added 20 tons they would add a halfpenny a mile. They could do better with their halfpenny per train-mile, he thought, than spending it in reducing a risk that was really very small.

With regard to the next point, he had travelled a good many thousand miles on express engines in England and America. He used to think that the driver of a locomotive had a marvellously difficult job to perform. Since then he had travelled thousands of miles in a motor car, and it had impressed itself upon him that driving a locomotive was a mighty easy job. There was no steering to be done, and there were no animals to be avoided. The road was fenced. Locomotive drivers really had not anything to do except to look out for the signals. The time that it took to close the throttle and reverse the lever was only momentary. He could not see what would be gained by their having another man in front, because he could not communicate instantly with the man who actually had the control of the throttle. Cost but not safety would be increased.

With regard to the list of accidents given on page 269 of the paper, he was bound to say that he thought that there was a question that engineers might look into. The number of failures of couplings was given as 2,440, and he wanted to ask engineers whether they did not think that it was about time that English railwaymen gave up playing with toy chains which they did their best to snap every time they started a goods train. He suggested that it was really time to couple trains in a less archaic manner.

As to collisions, the impression left on his mind after reading for many years the reports of the Board of Trade, was that they were nearly always the result of a combination of more than one cause, except where there was a sheer mistake on the part of an individual. Collisions happened where it was necessary that vehicles should be brought together. Mr. Enock spoke of a railway where there was to be nothing of that kind whatever; but surely it was going to have a terminus and was not going to run in a circle.

If they were to have single units running, as Mr. Enock suggested at the end of his paper, how were they going to carry anything like the traffic that a modern railway was expected to carry? On the underground railways, with an extraordinarily elaborate apparatus for signalling, they could get a procession of identical units all moving at the same speed at about 1¼ minutes apart. But if passengers were carried at a hundred miles an hour on the same rails with all the miscellaneous slow traffic, long intervals would be wanted between the units. If the passenger units consisted of a single coach they would never get a reasonable amount of traffic over the line. The only justification for a scheme of that kind would be the development of traffic to such an extent on a line, say, from London to Brighton, that they could afford to make a road which would carry one car every ten minutes or something of that kind, ignoring all intermediate points. But was it necessary to go in for such entirely new departures to get higher speed? What were the facts? On an existing railway in Germany trains were run at 120 miles an hour with electric power. At Brooklands a speed of 130 miles an hour had been attained with a motor. That could be done again to-morrow if they chose to put in the power. But they could not expect to do it with a steam engine under the normal conditions. The locomotive developed, perhaps, a thousand horse-power, hauling, say, 300 tons. They were using about 3 horse-power per ton; but an ordinary motor running on the road had something like 1 horse-power for each hundredweight instead of for six or seven hundredweight. A racing motor had anything up to 80 or 90 horse-power for a weight of, perhaps, 30 hundredweights, or 2 or 3 horse-power per hundredweight.

If they wanted speeds like that on the existing rails of to-day they could be got. But what were the speeds existing in practice at the present moment? Forty-three miles an hour was a commercial and not an engineering maximum. The fastest trains in the world have been running for more than ten years past from Philadelphia to Atlantic City. These trains are booked to do 55½ miles in 48 minutes. The company once ran this train special for himself and a party of English friends of his in 42½ minutes for the 55½ miles. No new system was wanted in order to get much better results if they could afford to pay for them.

On page 276 Mr. Enock dealt with the question of land, but he (Mr. Acworth) did not think that the comparison made was fair to English railways. He did not deny that the figures were correct, but they did not really represent the facts, because the single track miles excluded sidings.

In the Board of Trade returns each mile of single track of running line in England had, he thought, attached to it about half a mile of siding (speaking off the book). There were about 20,000 miles of siding, so that there were really about 50,000 miles of railway track in the United Kingdom. The corresponding figure for America was very much smaller. An addition of one-tenth to the running track mileage would probably represent all the sidings.

The typical thing that in England we called a railway was not the same as a railway in the United States. There the greater part of the area was very flat compared with England. The railway in the United States was made on the ground level; there were no bridges, no viaducts, and no tunnels. He had never seen figures on the point, but he was inclined to think that there were more miles of tunnel in England than in the United States. In England, the whole railway, being obliged to cross above or below the high roads, had to be made on an artificial level. The difference in the cost of construction on that account was enormous. Again, he once asked the engineer of one of the great English railways what was the cost of the platforms at an ordinary roadside station on a main line. From the figures given to him he came to the conclusion that such a platform, long enough to accommodate a main line train, cost about a thousand pounds. On the United States lines there were no platforms.

Then, too, the capital figures were not comparable, because the American figures did not represent cost. The President of the Pennsylvania line stated officially that his company had spent on the road in twenty-five years nearly £50,000,000 out of revenue. That process had been going on for the last ten years, on an enormous scale, in regard to nearly all the great companies. He was quite sure that the figures at which American railways were now capitalised represented nothing like their actual cost.

He was sure that it was an error to believe that any large percentage of the cost of English railways was due to the cost of land. Capital expenditure nowadays was mainly on widenings, which clearly were made in the places where land was most expensive because they adjoined big main lines. And even there, as anyone could see who would examine the half-yearly accounts of the different companies, the cost of land was only a very small part of the total cost. The real cost was constructional cost. Nobody doubted that purchase of land had absorbed a larger part of the capital in England than it had in America. When railways were made in Chicago they were put down in a field, and the town grew round them; but when the Great Central came to London a few years ago, hundreds of houses had to be pulled down. He expected that every engineer agreed that the cost of English railways was higher than it should be, because every engineer who had had experience of getting railway Bills through Parliament knew how much the cost of construction was increased by the demand that railway companies should spend a sovereign in order to do half-a-crown's worth of good to somebody. Parliament was very tender about alleged inconvenience to private individuals. And local authorities were even greater offenders. Parliament imposed expenditure out of all proportion to the benefits that were obtained by the people who asked for them.

He would ask Mr. Enock to notice one thing which arose from his saying that fruit rotted on the ground because the cost of transport was prohibitive. He (Mr. Acworth) ventured to suggest that if anybody would look into the facts as to how the difference in cost between the original producer and the ultimate consumer was made up, he would find, no matter where the goods came from, that the bulk of the cost was not made up of transportation cost, but of distribution cost. He had often wondered why nobody took up that question. He was sure that, when they came to look into it, they would find that the actual railway cost was very often quite the smallest part of the difference between what the producer got and what the consumer paid.

Mr. Ernest Benedict said that, although the paper contained many statements with which he could not agree, the author had shown proof of great enthusiasm in his ideals; these, from his (Mr. Benedict's) personal experience, had been the ideals of engineers ever since he had known railways. The true engineer tried to do the best for his employers, to work as cheaply and as quickly as he possibly could, and to make everything of the best so that railway travelling should be as safe as possible; while at the same time bringing his labourers along with him. The oldfashioned school of engineers looked upon the men that helped them as men and—if he might put it so strongly—as brothers. He was afraid that that feeling had much weakened, but it ought to be encouraged, and the labourers should be taught that it was to their advantage to give the best work at all times instead of doing as little as they could for their wages. He was, however, afraid that that result could only be attained under present conditions by a system of co-operation. A workman's pride in his work for the sake of the work was almost a thing of the past; failing this, the labouring man must get something out of the work financially or he would not improve his output.

The author had made many suggestions for increasing the speed, the security, and the economy of railway working. But every one of these increased the cost of the railways; and, in his (Mr. Benedict's) opinion, the only way in which some economy could be effected on the railways as they were was by getting better work out of the men. The principal means for bringing about great economies was very much more simple and effective than anything suggested in the paper. It was by inducing the public, Parliament, local authorities, and everyone else, as well as the labourers, to abandon that vicious groove in which they had been moving from the beginning, and no longer to regard railway companies as milch cows, for all these classes have always tried to get as much as they could out of the railways. If that state of things could be stopped, and if the railway companies could be relieved of the enormous rates and taxes which they had to pay and of the luxurious accommodation upon which now-a-days everybody insisted, a useful amount of saving would ensue. He could look back to a time before the majority of those in the room were born. The accommodation demanded in these days was very different from what it was when he first travelled down to Plymouth with Mr. Brunel in the year 1848. Then luggage was piled on the tops of the carriages, and the third-class passengers were carried in what we should now call cattle trucks. There were no Pullman refreshment and sleeping cars sixty or seventy years ago.

The author proposed to increase the safety of railway carriages by making them heavier. That, of course, involved cost. If these and other greater traffic facilities were wanted they must add to the number of their lines, and where there were now two lines they ought to be in a position to lay down three, four or five parallel lines. Then more trains or faster trains might be run. This could be done for less money than in procuring land and wayleaves and constructing a special line and rolling stock on Mr. Enock's plan. However, it was impossible nowadays to raise capital for any such purposes under any practical terms, in consequence of the obstructions put in the way of railway companies, to which he had alluded.

The author had proposed that the land for railways should be given by the Government, an excellent but rather belated recommendation as regards England. The Government of India had always made a free grant of any land required. If the Government in England wanted to do anything for railways they could do it in the way that he had pointed out.

With regard to accidents to employees, was it not well known to everybody that had anything to do with railways that, almost invariably, the accidents arose from the men's own carelessness? "Familiarity breeds contempt." A man would work on the lines and forget the danger, and while he was intent on what he was doing he would get run over. Such things could not be helped. They could not cause every regulation on a railway to be properly carried out; some risk must be taken.

He quite agreed with Mr. Acworth that it would be of no use to put another man in front of the engine. What would the poor man do if he was travelling at 60 miles an hour in a snowstorm and could not see anything at all? He would not be able to use the binoculars in such circumstances; and, if he was put in a cabin in front, he would probably go to sleep. He did not think that it would be possible to adopt the author's suggestion, which, moreover, would involve additional cost.

Then there was the question of attention. Train hands should always keep a keen look-out, but he was afraid that some of them thought that they could risk taking little naps occasionally. That engine driving, as Mr. Acworth said, was a comparatively easy job is proved by the fact that the natives in India drove their engines just as well as did white men elsewhere. They were not put on passenger trains simply because there was a feeling among Europeans that they did not like to trust a native with such a task. But all goods trains in India were driven by natives, mostly Parsis.

With regard to the buffer carriage which the author proposed to put between the engine and the train, what was to become of the engine in a collision? That was rather a dangerous thing to have in front of you. He was afraid that the buffer would be fatal not only to the engine driver, but to the guard, as Mr. Acworth had pointed out, and such a carriage would be an additional expense to build and to work.

Mr. R. J. Simpson referred to the statement made by the author, on the first page of the paper, that the world's railways were still killing and maiming large numbers of people. On the second page the author gave a table showing the number of killed and injured on the railways in the United Kingdom and the United States; but it seemed to him (Mr. Simpson) that the table was hardly fair to the railway companies, and that it was apt to give a wrong impression; for, if the table was looked into, it would be seen that the statistics were not nearly as bad as appeared at first sight. The author himself said, lower down, that, taking the number of passengers killed in the United Kingdom, only 18 of the 125 were killed owing to accidents on the railway. According to the Board of Trade reports, the remainder or most of the remainder were killed through their own stupidity either in attempting to get into or out of trains in motion, or by accidents due to their own carelessness. Practically the same remark applied to those who were injured. Out of the total of 3,502 only 534 were injured owing to what might properly be called a train accident.

With regard to employees, the far greater number of those killed and injured suffered through their own fault. A reference to the report of the Board of Trade enquiries into those accidents would show that fact. Notwithstanding the rules and regulations which were made for the men's safety, the men would persist in ignoring them. No doubt the large number of casualties in the United States was due to what the author called the spirit of independence in the American character.

Under the heading of "other persons," the author had given the figure of 577 killed in the United Kingdom. Before coming to the meeting he (Mr. Simpson) referred to the Board of Trade reports for the first six months of 1907, and he there found that in that period 226 of the persons killed were trespassers or suicides. He thought that few people realised how very popular a railway was for would-be suicides. It seemed hardly fair to include them in the number of those killed on the railway. It was not in any way the fault of the working of the railway that all those 577 persons were killed and that 959 were injured.

It also struck him that it would be fairer if Mr. Enock had shown a comparative statement beginning, say, thirty years back. He found that in 1880 the proportion of killed was 1 in 21,000,000; in 1890 that was reduced to 1 in 45,500,000; in 1900 it was 1 in 71,250,000; in 1909 the number was still further reduced to 1 in 126,000,000. This was the case notwithstanding the tremendous increase in the train-miles run. He thought that those figures would prove conclusively that engineers did not lack ingenuity in the development and in the working of railways.

With regard to the patent buffer which Mr. Enock suggested, it would appear that the one which he proposed to put in the centre of the train would, of course, do away entirely with the corridor. The author did not show any method of having a corridor in a train with such a buffer.

Major Hurlstone Hardy said that he agreed entirely with what the President had said in the communication which had been read to the meeting. He would say, in addition, that, England being so densely populated and commerce and travelling being so generally provided for, railway engineers were tied to the present system. In some other countries and in other circumstances there was a possibility of introducing novel methods, but British railways were practically tied to the development of existing methods, and were also tied with regard to expenditure. Moreover, there had been a great rise in the price of material and labour and in the demands which were made by the public. All these things tended to increase expenses, whilst the commerce of the country demanded cheaper transport for goods, and particularly for food. The produce of British growth competing with imports from the Colonies would in future suffer heavily if English railways could not keep down traffic charges.

With regard to new light overhead railways and schemes of that kind, he thought that the only possibility of development in that direction was that they could be developed experimentally in England prior to their application abroad in places where the ordinary railway could not for the present be economical.

There was a point to be considered in relation to economy. Up to the present time railways had had portions of the country allotted to them by Parliament for their sole occupation, but these areas were now being encroached upon by motor traffic. The railway companies at first had the traffic of a district with a certain amount of naturally limited competition between rival lines, but they were not then exposed to the competition of heavy goods motor traffic, which broke down public roads repairable out of the local rates. Such competition was unfair to the incorporated railway companies, and if it was allowed to a very large extent would deprive the railways of part of their fair profit in the future on the increasing income from carriage of goods and people. There was, as one might say, a contract which was supposed to be tacitly set up, when a railway was created by Act of Parliament, that the railway should have the heavy traffic of its district. But now that privilege was being taken away from them. The tramways, no doubt, properly competed for a great deal of suburban passenger traffic. The railways must pay a fair dividend, but with increasingly heavy expenses they would certainly be unable to conduct the public business as cheaply as formerly if they were to be deprived of what was their fair inheritance.

As to the idea of a light railway, which he would call a light aerial railroad, there was he thought a possibility of that kind of thing being introduced in undeveloped countries, but in a very different way from that which the author had sketched.

In this connection he was greatly struck with the possibility of effective propulsion when the author referred to what could be done in aeroplanes and what could be done in motor cars. When the screw was first proposed for marine propulsion he thought that the credit was not given to the proper party. Professor Benet Woodcroft, F.R.S., with whom he served for some years, had never had adequate credit for proposing the screw propeller in marine propulsion. The form of the marine screw propeller had been too closely copied by aeronauts. A radical difference of form was required when working in a dense and non-elastic medium and when flying in air. He felt sure that the screw propeller had possibilities of efficiency in driving power in an elastic medium which had not yet been reailsed. In fact, he knew that the aeroplane propeller was about to be made very much more effective than it was at present. He had ridden in light railroad inspection cars, and contemplated the construction of stronger and still lighter cars. Now, if they were to have a motor car so light that it could ride on a cheaply built aerial railroad, they might swiftly and safely cross the deserts of Egypt and other such places; but this was not suitable for England. The details of the development might thus be very different from what the author outlined. That was quite a distinct subject from the development of mono-rail and the like in England at the present time. The paper contemplated too great changes, which were impracticable in a densely populated country like England.

Mr. S. A. Stevens said that he, like Mr. Acworth, felt that he owed an apology to the meeting for trespassing on its time, as he was not a railway engineer. On page 269 the author spoke about accidents to shunters due to coupling and uncoupling. That subject had been considered by managers and engineers of railways for years, and despite innumerable attempts and experiments, they had yet to find a coupling which would be automatic and, at the same time, interchangeable with the existing coupling.

On page 270 the author said that carriages were not built to stand collision. He (Mr. Stevens) emphatically differed from him on that point. In his early days he was connected with a railway. He knew that in breaking up a carriage which had been in use for over 20 years on the much maligned Chatham and Dover Railway, sledge hammers had to be used because the carriages were so well built. He thought that modern railway carriages were models of construction for the purposes for which they were intended.

The paper throughout its whole length dealt almost entirely with passenger traffic, and goods traffic was left to take care of itself. Mr. Acworth had said that the cost of the carriage of goods was a very small item of expense to the consumer, but he did not agree with him. Over seven million tons of coal came to London in the year, the main portion of which was from Nottinghamshire, Derbyshire, Leicestershire, and Warwickshire. The average cost of the coal at the pit was 8s. to 9s. The average cost of the rail carriage was almost the same figure.

Mr. Acworth, interposing, said that the cost to the consumer had just about as much again added to it to get it from St. Pancras, say, into the consumer's cellar. That was an extreme instance, but he was not talking of coal.

Mr. S. A. Stevens, continuing, said that all the same he could not agree with Mr. Acworth in any way. He wished to emphasise the need for cheaper transit.

A point that he wanted to make very strongly was that nothing was said in the paper about the improvement of goods traffic. If goods trains could be run at 60 miles an hour, if there were improved methods of dealing with goods trains, lines would be very much less occupied by them than they were at the present time, and as a consequence travel would be enormously facilitated and quickened.

The question of signalling was another point. The present system in England had grown out of numberless Board of Trade regulations. It was safe beyond doubt, but it was equally beyond doubt that, if only a system of automatic signalling were brought in, it would save an enormous amount of time.

Another point was that the present road locomotive, whether a bicycle or motor car, had ball bearings. Sir George Gibb tried a system of ball bearings on the North-Eastern Railway, but it was not altogether satisfactory. With such bearings a train would want less tractive power to haul the same weight, and could travel much faster and at less cost.

He thought that the author, in his table of certain train speeds, was very unfair to railways in England. He put the slowest journey between London and Plymouth as eight hours, but it must be remembered that trains must stop at certain places, however much it was desired to fly across the country. A train such as that was not intended to get from one end of its journey to the other in quick time.

Mr. E. Kilburn Scott said that labour unrest on railways, although regrettable in many ways, had a bright side to it, and that was that it was likely to give opportunities to inventors and engineers. There was more likelihood of improvements in machinery, etc.,being adopted when there was trouble with labour, than when labour was quiet.

In the paper the author mentioned that a line was wanted in this country where railway experiments could be carried on, which experiments should be financed by the companies alone or with help from the Government. That was exactly what occurred on the Zossen line near Berlin, where two electrical companies and a company making rolling-stock joined with the Government in a syndicate to study and test high-speed traction problems. The railway line used was a strategic and not a commercial line, and so the experiments could be carried on without interference from ordinary traffic. We need not go to the Yorkshire moors for a place for an experimental line; there were plenty of places in the South of England (Kent or Surrey) near the Continent where a strategic railway would be useful; that is to say it could be placed where it would not carry much traffic in the ordinary way, but it would be there in case of war. Germany did a very great deal for the engineering world in publishing the results obtained on the Zossen line. The German Government and the firms who financed the experiment are very much to be commended for it.

The high figures for coupling accidents staggered him, and it was high time something was done to reduce them. He had an idea that, on electric railways at any rate, electric current might be utilised in connection with the coupling. He did not see how carriages could possibly be coupled together with an electro-magnet although the electro-magnets were doing wonderful things in crane work; even locomotives could be lifted by them. Possibly there might be an opening for electricity to operate a catch for the coupling hook.

He wondered why somebody had not raised the point of the nationalisation of railways during the discussion, as the paper seemed to call for a remark on that point. He used to live on the South-Eastern line, and when a train was stopped on one of the bridges, or came in late, the remark was commonly made, "I wish that railway lines were nationalised." His experience of nationalisation was such that he did not want to live in a country whose railways were nationalised. Four years' experience of nationalised railways in Australia had brought him to the conclusion that, instead of being a nation of grumblers at railways, the people living in Great Britain ought to be very pleased indeed with the fine services that they were given by the companies. His distinct opinion was that with regard to railways we were the best served people in the world, and we were certainly very much in advance of countries where the lines were State-owned.

Mr. A. S. E. Ackermann said that he would like the author in his reply to reduce the statistics relating to the killed and injured to killed and injured (respectively) per train-mile and per passenger-mile, as he thought that there was some unfairness to America in the way the facts were stated, e.g., in the United States the single-track mileage was, according to Mr. Enock, six times that of the railways of England. Multiplying the English figures by six immediately reduced the apparent discrepancy between the two countries. Probably the rates per train-mile would give another aspect to the case.

He took it that the figure of 1 in 83 millions, the last paragraph but one on page 268, referred to England. The author might add the corresponding figure for America if he had it.

He would like to know how the steel coaches which were used so much in America behaved in railway accidents. There they apparently had plenty of experience of railway accidents, and consequently it ought not to be difficult to get particulars as to how the carriages behaved in a collision.

Mr. E. W. Chalmers Kearney wrote: The subject of Mr. Enock's paper is of peculiar interest to me, as I have devoted my life to the problem of high-speed transit. I did not start out as an inventor with an idea to exploit, but merely with the conviction that something had to be done to improve the present means of transit, and with my mind entirely free as to the best means to adopt. For the first four years (1902-6) I did nothing but research work, examining during that period every system—and the number was very large—that claimed high speed as a characteristic. I found none that I considered practicable, and it was only then that I determined to design a system myself. Armed with the wealth of information on the subject which I had gleaned by research, it did not take long to decide upon the broad features of the system which is now known as the Kearney High-Speed Railway. From 1906 to the present time has been devoted to experimental work and to the gradual improvement of the system in detail, and I can now fairly claim to be in a position to design and supply a railway capable of maintaining the high velocities forecasted in the paper. In England, however, inventors and promoters of new ideas are looked at askance, and every possible difficulty is thrust in their way. One has to suffer much through misrepresentation and even personal abuse.

On several occasions public demonstrations of my models have been rendered futile by deliberate mutilation—electric wires have been cut, rails removed or bent, and once the whole of the supports to one of the stations were sawn through!

What I regard as essentials in any high-speed railway system likely to prove a commercial success may be tabulated as follows:

1. Absolute safety from derailment.
2. Economy in construction.
3. Simplicity, especially at junctions.
4. Low working costs at high speeds.

In the Kearney High-Speed Railway the first essential is met by the provision of a single bearing rail, which eliminates lateral oscillation, in combination with a single overhead guide rail. The carriages are held securely in position between the two by specially grooved wheels and clips which permit the cars to run freely at all speeds. No derailment can take place unless there is an actual rupture in the permanent way. It should be borne in mind that with a single bearing rail employed most of the factors are absent which commonly tend towards disaster.

The second essential is met by utilising the guide rails of the up and down tracks for mutual support by means of cross bracing. In effect this gives a lattice girder 13ft. deep, which permits of the necessary strength being obtained with the employment of a very small amount of metal. As now designed the superstructure of the Kearney High-Speed Railway will take a side load per car length of over 7 tons with a factor of safety of 2½. As the side pressure is never likely to exceed 2½ tons per car, the actual factor of safety is over 6, which compares very well with the accepted factor of safety of 1.7 for ordinary railways. Comparing the actual cost of a double track—permanent way only—of twin-rail and Kearney systems, the latter will show a slight advantage only, but if the difference in grading required and saving on route mileage is considered an economy of from 50 per cent. to 60 per cent. can nearly always be shown by the use of the Kearney system.

The third essential of simple construction is well met in the method I propose, and the ease with which switching operations can be carried out at junctions is a characteristic of the system. Most inventors of high-speed railways, I find, seem to ignore the necessity and fail to make provision for junctions, but one or two have gone further, and actually put forward this serious disability inherent to their respective systems as an advantage!

The fourth essential is covered by paying careful attention to the shape and exterior surfaces of the carriages, with a view to minimising air resistance, which increasing by the square of the speed, soon becomes the largest factor affecting the output of power. The use of ball bearings, which I find are quite satisfactory on vehicles running on a single rail, will also play their part in a lesser degree. Rolling resistance is so unimportant compared with air resistance at high speeds that I am of opinion that ball bearings will be used not so much for the sake of the power they will save as their freedom from liability to heat up. I calculate that a Kearney High-Speed car of 20 tons could maintain a speed on the level in still air of 120 miles per hour with an output of 269 h.p., of which 250 h.p. would be used in overcoming air resistance.

The above would seem to clash with the author's proposal for a "Rail-Airplane." It is almost certain, in the face of the high value of air resistance, that the planes would consume more power than they saved by reason of any lightening of the weight on the wheels. Against this must be set the advantage gained by reducing the wear and tear of the permanent way, but there would certainly have to be a limit to the "lift," as, even with a motor fitted to every other wheel of a train, half the weight of the train is required to give the necessary adhesion for tractive purposes at 200 miles per hour. I do not think there would be any advantage in transferring the pressure required to the overhead rail, even if this did not present a difficulty in designing the overhead structure to withstand it.

With regard to the author's suggestions regarding cross-country overhead railways I fear the lightest that could be erected with due regard for safety would greatly exceed in cost that for a surface line including land. The Liverpool Overhead Railway cost £90,000 per mile, and even the comparatively light structure required for the Kearney High-Speed Railway, where the whole weight of the train can be concentrated on a single plate girder, the cost would run to nearly £50,000 per mile.

In connection with mountain railways it is interesting to note that, with an electric train with a motor on each axle, the present maximum gradient of 1 in 20 can be increased to 1 in 6½. Further, as rise and fall affect speed inversely as the speed, high-speed trains will have the additional advantage of being able to "rush" a mountain side set at any angle that passengers will face—e.g., a train travelling at 200 m.p.h. could negotiate a gradient of 1 in 2½ (say) and climb to a height of 1,000 feet, and still be running at 100 m.p.h. at the top, this solely by virtue of its own kinetic energy.

The velocity head of a train at			30	m.p.h. is about		30	feet.
,,	,,	,,	60	,,	,,	120	,,
,,	,,	,,	100	,,	,,	332	,,
,,	,,	,,	120	,,	,,	480	,,
,,	,,	,,	150	,,	,,	752	,,
,,	,,	,,	200	,,	,,	1,328	,,

The natural law at work here is a fortunate one for the future of high-speed railways, while it accounts for the great variation between maximum, minimum and average speeds characteristic of our present railways. A train at 60 m.p.h. encountering a sudden rise of 120 feet is brought to a standstill, supposing its power to have been cut off at the foot of the gradient, while if a train at 120 m.p.h. is similarly treated the effect is merely to reduce the speed at the top of the hill to 100 m.p.h.

The Author, in reply, said that he was glad to have aroused so much discussion, although he might have wished that the criticism had been more constructive and less destructive. Possibly destructive criticism was inevitable in view of the character of the subject, and the customary tendency to attack new ideas. He thanked the Chairman for his remarks about idealism, because the paper was of course written partly from that point of view. He believed that imagination must precede a good deal of what engineers had to do, just as it had preceded great movements in the past. As an example, they would recollect that America was discovered by the imagination of Columbus, aided by the cash obtained from the jewels of Queen Isabella.

He was pleased to hear the President's letter read, and regretted that that gentleman, as an authority on railway matters, had been unable to be present.

It had been said by Mr. Acworth that the guard might object to riding in the proposed buffer carriage. There was no doubt that the guard objected even at the present to being smashed up in his own private compartment in the front of the train, which happened occasionally, but the proposed carriage would protect him. As to the weight of the buffer carriage, that was an item to be considered, of course ; but it must be recollected that there were often three, four or more empty coaches in trains, which were practically dead weight, possibly because there were not enough passengers to fill the train, but also because, as he said in the paper, passengers distrusted the front coaches. The buffer coach was rather to replace those empty coaches.

As regarded a special man on the look-out, that was only a suggestion, but he thought that the criticism which had been directed to it had not taken its possibilities into account. Mr. Acworth had said that the man on the look-out would not be able to communicate with the engine driver—for example—in a snowstorm, but most of those present, doubtless, had travelled on ocean steamers, possibly in snowstorms and gales, and they knew that the man on the look-out had no difficulty in communicating with the proper official in emergencies.

Another point made by Mr. Acworth was in regard to specially quick trains in the United States, and he had given instances of some very rapid journeys. Of course those abnormal speeds could be reached, but lives were risked in doing it, and that was what he thought they should endeavour to obviate in a new type of construction.

As to the matter of land, the figures which he (the Author) had given for single-track mileage were taken from the Encyclopædia Britannica. They were there, put in the way in which he had given them. Possibly they were capable of some modification, but with regard to the relative cost of construction in the United Kingdom and the United States, the cost of the best railways in the latter country was given at practically the same figure as the cost of construction in England, without the land. There was therefore no doubt that the cost of land in England had to a large extent—if not quite so much as appeared—figured in the greater cost of English railways, and in the interest of the community this cost ought to be lowered in the future.

Co-operation had been referred to by Mr. Benedict as a probable remedy for the labour difficulties that had been witnessed. Although that was not a point which greatly concerned engineers, it was, nevertheless, inseparable from the present subject ; and, for his part, he believed that co-operation or profit-sharing would furnish the solution of the difficulties, not only in railways, but in other industrial matters. He believed that the ideal relations of master and servant, however much it might be regretted, belonged to the past; and that the labourer was now beginning to think that he was worthy of a better hire. Society was turning over very greatly, and it was absolutely useless to close their eyes to the fact.

The matter was also touched upon by Mr. Kilburn Scott when he spoke of the nationalisation of railways. No suggestion had been made in the paper that railways should be nationalised. He (the author) had not gone into that aspect of the subject very much, but he did not think that he should advocate it. In some countries he had visited, where many of the railways were owned by the Government, they were badly served. The danger of railway nationalisation, it seemed to him, would be that railways would tend to become machines for political and other favourites, and nepotism generally, and under such conditions they would not give an efficient service. Rather than nationalisation he would suggest co-operation and profit-sharing.

Complaint had been made by Major Hardy of the unfair competition of electric trams and motor traffic with railways, but were the railways doing their utmost to compete? The fault might not be theirs, but it might be the fault of a moribund system. Those who had followed the discussion in the Press lately, which had been brought about by railway strikes and so on, would have seen indictments made against railway management in an economic sense. He had with him a cutting from an article in the *Fvening News* of September 19th, 1911, which periodical could not be accused of being a Socialist or anti-capitalist paper, in which there was an indictment of the wasteful methods employed, especially in the handling of goods traffic.

The same speaker had said that the system of light overhead railways, such as the paper suggested, were not suitable for England, but might be useful for Egyptian deserts. But why? If they were practical in an undeveloped country why were they not so in a developed country, and even more so where the value of land was considerable and still growing?

It had been said by Mr. Stevens that there was no mention in the paper of goods traffic. He (the author) had not gone very much into that question for he was mainly occupied with a quicker and more economic conduct of the passenger traffic; but he did not neglect the goods traffic altogether, and he believed that the principle which he advocated of swift individual vehicles even for freight traffic was feasible and advisable. They saw how easily goods were carried in steam lorries in the streets, and that, he thought, gave an example of the possibility of handling goods in that way on the railway. This, of course, was to be taken in conjunction with what had been said in the paper about new types of railways, to overcome heavy gradients, especially in mountainous regions.

With regard to the question of speeds, of course the averages included the slower trains, and his idea was to show the general times of travel, and that, in his opinion, travel was too slow.

He did not, in his paper, make much mention of the mono-rail. He simply put in a sentence, which he had not read to the meeting, saying that it might have some adaptation or development. He really knew very little of the mono-rail, and when he had heard first of it he did not greatly believe in its commercial practicability.

Complaint had been made by some speakers of Parliamentary and municipal restrictions and regulations, and the heavy rates, and so forth, against which railways had to contend. It was a fact that railways seemed to labour under these burdens, but he thought that it was part of the duty of the engineer to create, or to help to create new systems which would give the Government and people confidence, and which would enable burdensome regulations to be removed, and bring about cheaper and better methods of travel which in time would supersede the old ones.

He must stick to his colours in regard to what he had said about scope for imagination and experiment in the matter of railway science. He believed that it would be advisable to bring about some national experiments, and that idea was supported by one speaker. He maintained that there was room in railway engineering work for greater ingenuity and new methods.

The author also communicated the following supplementary remarks :—

I have received a number of Press cuttings reporting the lecture and various letters from private individuals showing the matter to be of public as well as technical interest. In the *Evening News* article referred to in my reply, which deals primarily with Mr. Gattie's scheme for a central clearing-house for goods in London, the writer points out that there is at present enormous and unjustifiable waste in our transport system, and that if that waste were checked by the adoption of some such scheme as Mr. Gattie's the companies would be enabled to pay their men more, simply because, under improved conditions, that abour would be worth more. The article in many respects supports the arguments I advanced for more scientific management. Of course, the managers may have something to say for themselves. I would, however, once more draw attention to the matter of half-empty passenger trains, and ask if single motor carriages, run at the slack hours of the day, would not at least economise fuel. There was no reply to this point in the discussion. A few weeks ago I journeyed to Portsmouth from Waterloo by a mid-day train. This train was of great length, but there was no passenger except myself in the compartment I occupied, and I particularly noted many coaches without passengers at all. Do railway shareholders care nothing about the consumption of coal, to say nothing of useless wear and tear upon rolling stock and permanent way?

In my opinion—pending estimates I am having made—the cost of light overhead railways would be less than that of the present system, which is also too cumbersome, and I believe that light overhead lines, such as advocated in my paper, would give a great impulse to travel, and that these lines could be constructed at half or less than half the present cost. It does not necessarily follow that existing systems would be relegated to the scrap-heap.

6th November, 1911.

H. C. H. SHENTON, VICE-PRESIDENT,

IN THE CHAIR.

TWO-STROKE CYCLE ENGINES.

By ROBERT W. A. BREWER, A.M.Inst.C.E., M.I.Mech.E., M.I.A.E.

[FELLOW.]

THE enormous development in mechanical transport which has taken place during the last few years has been achieved by a gradual perfecting of the internal combustion engine, with the development of which the name of Mr. Dugald Clerk stands out prominently as being that of probably the most persistent and scientific investigator on problems connected with this type of engine; a type which, practically speaking, has ousted all other movers, whether they be primary, such as the steam engine and boiler, or secondary as the accumulator and electric motor.

Internal combustion engines may, roughly, be divided into two classes, namely, those working on the two-stroke cycle and those working on the four-stroke (or Otto) cycle, the former of which Mr. Clerk has been investigating since 1877, his first practical and complete engine being exhibited at the Kilburn Exhibition of the Royal Agricultural Society in 1879. In this engine there were two cylinders whose pistons were connected to a shaft having two cranks. One of the cylinders took in a mixture of gas and air and compressed it into a chamber at the back of the working cylinder. From this chamber the working cylinder received its charge through a slide valve, which also acted as an ignition valve, ignition being effected by an incandescent cage of platinum kept in a heated state by the successive explosions. This was the first explosion compression engine to give an impulse at every revolution. The first cylinder was used as a pump to deliver the mixture into the reservoir at a pressure of about 70 lb. per square inch.

In this engine Mr. Dugald Clerk sought to combine the advantages of compression before ignition with the complete expulsion of the exhaust gases, by reducing the clearance at the back of the cylinder to a minimum. However, great difficulties were met with in this, the first successful engine working on the two-stroke system, the chief of which were back ignition in the compression reservoir, and excessive shock in the motor cylinder. The latter difficulty was eventually minimised by modifying the shape of the combustion chamber, but the former was never overcome.

In 1880 an improved Clerk engine was built. This had a conical combustion chamber into which the charge was pumped through a mushroom valve, the exhaust taking place through annular ports in the cylinder walls when the piston was at a crank angle of 40° before the outer dead centre. The pumping was carried out by means of a separate crank set at an angle of 90° to the main working crank. In this way the explosive mixture of air and gas in the pumping cylinder underwent a slight compression during the firing stroke of the previous charge in the working cylinder. After the exhaust ports were uncovered and the pressure in the cylinder reduced below that in the receiver

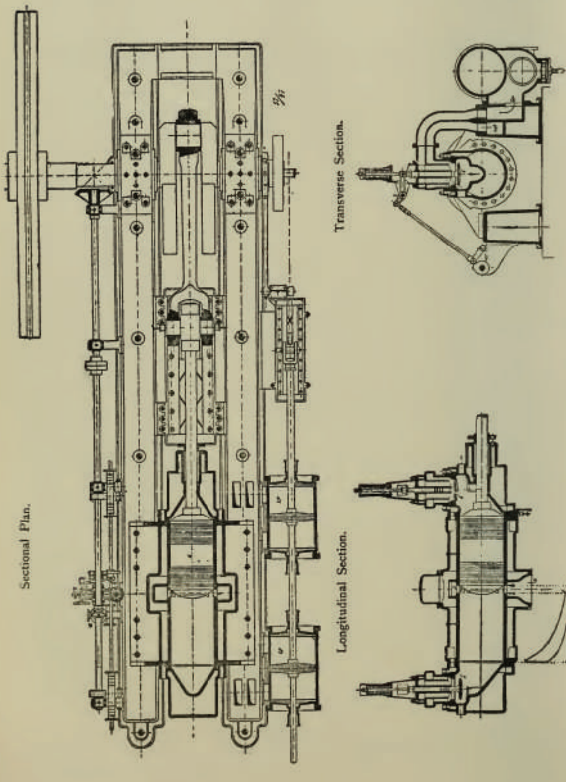


FIG. 1. —THE KOERTING ENGINE.

the fresh mixture passed automatically into the working cylinder. The final compression was carried out by the working piston on its return stroke.

Messrs. Koerting Bros. have for some time built large engines on the Clerk principle, but in these large modern engines it is only possible to obtain economical working, while avoiding the risk of firing the incoming mixture, by supplying the air and gas through separate pumps. The Koerting engine unit consists of a double-acting power cylinder fitted with a double-acting air-pump and a double-acting gas pump, these two being in line with each other and on the same piston rod. In a double-acting engine a most important relation exists between the length of the piston, the stroke, and the exhaust ports, which are placed annularly round the cylinder. The piston must be of such a length that these annular ports are not overrun more than is necessary for their complete uncovering, and the piston must therefore be of a length less than the stroke by an amount equal to the width of the exhaust port.

Large two-cycle gas engines are almost invariably used in connection with a fuel of low calorific value such as producer or blast-furnace gas, whose value is of the order of 100 to 150 British thermal units per cubic foot. This quality of gas is difficult to obtain free from dust and traces of tarry matter ; for this reason successful working can only be obtained when efficient scavenging takes place. In an engine of the type under consideration, where two separate pumps form essential details of the design, scavenging can be carried out in a simple manner by arranging the distribution valves so that the blast of air precedes the charge of gas at the end of each stroke. It will be necessary to bear in mind this important point in two-cycle work, because one of the great difficulties to be encountered in running engines under variations of load and with different proportions of mixture or attenuations of charge to meet such conditions, is to keep the engine working on the two-stroke and not on the four-stroke system. This peculiarity of the two-stroke engine will be referred to later on.

The two-cycle engine should have the following advantages over the four-cycle engine for large powers :—First, the working volume of the power cylinder for a given output should be one-half of that required for a four-cycle engine at the same speed ; second, in a two-cycle engine design the exhaust valves should be eliminated. These, in large engines, are a source of some anxiety on account of the power required to lift them, and the excessive heating to which they are subjected. Thirdly, weight for weight, a two-cycle engine should be considerably more powerful than a four-cycle engine, or conversely an engine of equal power can be much lighter when working on the two-stroke principle ; and, fourthly, the working pressures in a two-cycle engine can generally be lower than in a four-cycle engine.

In the larger powers numerous mechanical difficulties are met with, as in the construction of very large pistons in single units and from the fact that a limiting value of dimensions has been almost reached under the prevailing conditions of working and materials obtainable. As this paper is intended to deal with small high-speed types of two-cycle engines one may be tempted to think that the conditions prevailing in large engine practice were of little interest to the automobile engineer. However, what has already proved a practical system on a large scale is daily becoming more appreciated for smaller powers.

The two-cycle engine has been manufactured to a considerable extent in America, principally for use in motor boats, but there is no reason why it should not take the place in motor car work which this type of engine might be expected to occupy on account of the possibilities of weight reduction and power increase theoretically attributable to it.

Two-cycle and Four-cycle Engines Contrasted.

To some it may seem futile to consider at all the possibility of supplanting the Otto cycle engine—even to a limited extent—by the two-cycle engine. During the past twenty years the attention of engineers has been concentrated upon the Otto cycle, and it is therefore only to be expected that this type of engine should be in a state of practical perfection after so much thought and labour have been expended upon it. On the other hand, the two-cycle engine problem has been tackled by comparatively few, but there are now several very excellent two-cycle engines doing regular work with economy.

The two-cycle engine problem is a very difficult one, and in he past the following have been the principal defects, viz. :—

(*a*) The difficulty of controlling the speed and the power.

(*b*) The loss of unburnt charges down the exhaust pipe.

(*c*) The variation in the composition of the mixture due to attenuated charges and misfiring.

(*d*) The difficulty of *entirely* displacing the burnt gas from the cylinder, and filling it with a new charge ; and

(*e*) The excessive fuel consumption.

Considering first the most difficult problem, namely, that of dispersing the products of combustion by a complete cylinder-full of fresh mixture. If this operation can be effected, the power obtained from any one cylinder working on the two-stroke principle should be theoretically more than double that obtained from the same cylinder on the four-stroke principle, the proportionate increase of power being represented by the ratio of the compression volume to the total working volume. Clearly this should be the case, as in a completely scavenged cylinder the compression volume, as well as the working volume, will be filled with an explosive mixture.

By comparing the losses in a two-cycle and a four-cycle engine and investigating their causes, we can endeavour to come to some conclusion as to whether a small two-cycle engine can be reasonably expected to compete with a four-cycle engine. Supposing that, with equal cylinder dimensions, we can obtain more power from the two-cycle engine, it will not be necessary to increase the size and weight of the connecting rods and of the crankshaft, and these portions of the material will therefore be more efficiently utilised. Conversely, for equal powers, the two-cycle engine will be the smaller, the lighter, and in all probability the cheaper of the two, power for power.

As regards loss of heat to the water-jacket, there is very little to choose between the two types, this being in either case about 3,400 to 3,880 B.T.U. per I.H.P. hour, say, 35 to 40% of the total heat in the fuel.*

Charging Arrangements.

With regard to friction and pumping losses, we will take a case where the charge is supplied by a separate pump. A two-cycle engine is somewhat at a disadvantage from the fact that the volumes of air required for combustion must be handled by two separate cylinders. Assuming an equality of the other conditions, this might be expected to involve greater pumping losses in a two-cycle as compared with a four-cycle engine, but the increase of movement of air and gas does not involve a large percentage of extra work, and we may take it that in a small engine the pumping losses amount to a total for a two-cycle engine of 8 to 10% of the I.H.P., and for a four-cycle engine of 6 to 7% of the I.H.P.

Several methods of charging the cylinders of a two-cycle engine have been tried so as to comply with important conditions which must be fulfilled in order that this type of engine should justify its existence. It may be assumed that the two-cycle engine will stand or fall by the efficiency of the scavenging arrangement of its power cylinder, and also that its reliability, capacity, and thermal efficiency will depend upon this. As a general rule also, an excess of air is indispensable in order to drive out the burnt gases effectually, as during this process turbulence is bound to be set up, and there will be to a certain extent an intermingling of the air and the burnt gas. Some of the air must therefore be blown out through the exhaust ports in every case where complete scavenging occurs.

It will thus be seen that in any arrangement of crank case displacement, *i.e.*, where the piston volume swept is the same

* Taking the calorific value of the fuel at 19,500 B.Th.U. per lb. and consumption = 0·5 lb per H.P. per hour.
= 9,750 B.Th.U. per H.P. per hour.

the loss of heat to the jacket $= \frac{3,400 \times 100}{9,750} = 35\%$.

on the crank-chamber side of the piston as on the working side, and the chamber itself is utilised as a compression volume for the charge, the maximum that can be hoped for in the way of new charge is a volume equal to piston displacement. Even this will scarcely be reached in practice, on account of the losses occasioned by the transference of heat from the cylinder walls and other masses of metal to the new charge.

There is another point to be borne in mind where crank-case pumping is adopted, namely, that the positiveness of the scavenge ceases when the piston reaches its outer dead centre, unless a receiver of sufficient capacity is interposed and a non-return valve fitted to prevent the air returning to the crank chamber on the upward stroke of the piston. It will be pointed out later on how such an arrangement also suffers by reason of the falling off in pressure of the air supply at a time just before the inlet closes, when a slightly higher pressure would be of considerable benefit.

A further feature in the crank-case system is that, when the front of the piston acts as a compressor, the heat transferred to the charge is considerable, on account of the unsuitable shape of the chamber in which the compression takes place and the leakage that is likely to occur through the bearings. It cannot be denied, however, that such an engine has the feature of simplicity in its favour, and where high efficiency is not a great point it has many things to recommend it.

We may take it now that high efficiency cannot be obtained with crank-chamber compression, and a number of designers have resorted to the use of pistons of two diameters, using the annulus for pumping purposes. In the engine designed by Mr. B. T. Hamilton, multiples of two firing cylinders are used so that when one of the larger pistons is on its ascending stroke, air is blown through above the other piston, which is at the bottom of its firing stroke, the cranks being set at an angle of 180°. An important feature of this engine is a distributing valve situated in the air pipe, for the purpose of admitting hydrocarbon vapour at the proper moment, the valve being rotary and mechanically operated so that any desired regulation can be obtained. In this simple type of engine, whether constructed with a pumping annulus or for use with crank-chamber compression, there is one inherent defect, namely, that the exhaust and inlet ports are in the vicinity of one another, while the exhaust ports are necessarily longer and remain open after the inlets are closed. The effective volume of new charge has a limited maximum, which, assuming that the products of the previous charge are completely dispelled, is only that of the compression space and the working volume to the point of exhaust valve opening and closing. In order to increase the charge volume which it is possible to put into a working cylinder on the two-stroke system, either the ports must be differently arranged, or the incoming charge must be admitted at the end of the cylinder opposite to the exhaust outlet.

The Lamplough rotary engine, though not at the time of writing a proved mechanical success, has at least a very interesting feature in the arrangement of the admission and exhaust. The cylinders are each fitted with a centrally situated mushroom exhaust valve in their heads, the inlet being through annular ports in the cylinder walls. As the engine is rotary there is the possibility that centrifugal force assists the inertia of the gases in exhausting the cylinders and at the same time the flow path of the incoming charge is a centrifugal one. The Author believes that there is considerable novelty in this arrangement of an engine. (Plate I.)

Passing now to another arrangement of two-cycle engine cylinders we will consider the inverted U type of engine, which is fairly well known. These cylinders are also known as the syphon arrangement and date back at least to 1900 when they were described by Binn, and in 1903 this arrangement reappears in the patent specification of Messrs. Bickerton, Bradley, and Dugald Clerk, of The National Gas Engine Co., Ltd. Here we have also a uni-directional flowpath for the gases, as the two legs of the syphon are combined with a common combustion chamber. The exhaust ports are cast in the walls of one cylinder, whilst the inlet ports are in those of the other cylinder. The advantage claimed for this arrangement is that a longer flowpath is given to the incoming charge and there is less likelihood of the incoming mixture passing unconsumed through the exhaust ports.

Were there such a phenomenon as perfect stratification, it would be possible so to arrange the pressure and volume of the incoming charge that none of it escaped down the exhaust pipe. In actual practice with high-speed engines there is, however, very considerable turbulence, and whatever the arrangement of the cylinders, there is a very great intermingling of the fresh charge with the products of combustion of the previous charge.

The Valveless engine is an example of this principle in actual work, and this engine has proved to be quite satisfactory in many respects. Mr. Reginald Lucas originally used a straight cylinder with two pistons moving in opposite directions, but afterwards reverted to the syphoned arrangement and fitted two crankshafts. In his engine the two pistons descend together and their centre line is transverse to the centre line of the crankshafts. In spite of the increased length of flowpath, this engine suffers from the same objection as exists in many single piston engines, namely, that the exhaust ports, which necessarily open first, close after the inlet port has closed. The ideal arrangement is to close the exhaust port as soon as possible and allow

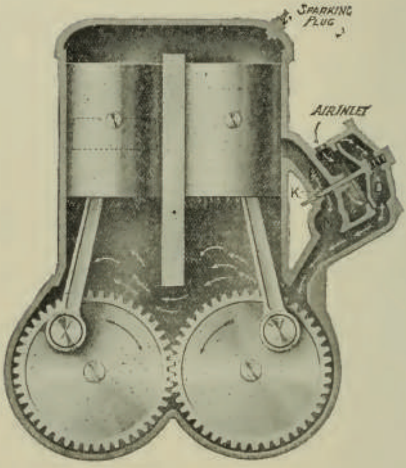


FIG. 2.—THE VALVELESS ENGINE.

the inlet port to remain open with the ever-increasing pressure of the incoming charge.

The arrangement of syphon cylinders in the Lamplough vertical two-cycle engine enables this difficulty of valve setting to be overcome, but at the same time the arrangement of the connecting rods and their design may call for some criticism from strictly engineering points of view. The syphon cylinders are set with their axis transversely to that of the crankshaft, and the two pistons in one unit actuate upon the same crankpin. The accompanying fig. 2, shows the position of the subsidiary crankpin for one of the rods. In this arrangement it is obvious that the two pistons do not synchronise in their movements, and it so happens that with equal port openings the exhaust is opened first and closed first, while, although the relative movement of the pistons is appreciable at the time of firing, the actual volume of the compressed mixture is constant at that moment.

In this type of engine a separate charging pump is necessary for each firing unit, but in carrying out numerous experiments, the author has obtained some advantage by coupling up two compressed mixture reservoirs in a duplex unit in order to increase the effective volume of the waiting charge. In this

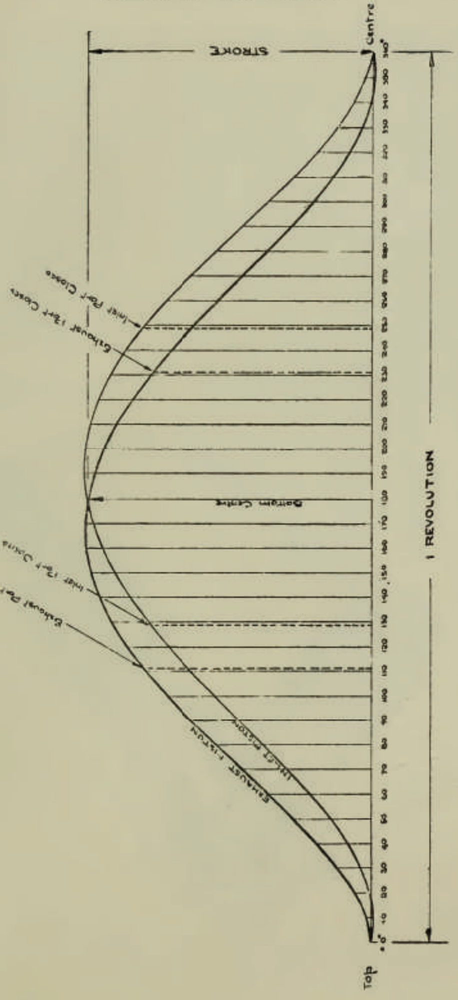


FIG. 3.—PISTON DIAGRAM, LAMPLOUGH ENGINE.

type of engine, air and vapor are dealt with in a single pump, and such scavenging as obtains is carried out by means of the carburated air.

A rotary arrangement as distinct from such a charging device, has many attractions. These rotary charging pumps have been exclusively adopted in conjunction with two-cycle engines for aviation purposes, and in addition to the large pulsating blower which Mr. Lamplough constructed for his aviation engine, there has been a considerable amount of practical demonstration of rotary charging devices by Messrs. Mort, of The New Engine Co. The arrangement of blowers adopted by Mr. G. F. Mort obtains by rotary methods a result similar to that adopted in the Korting engine, separate blowers being used for air alone, and for carburated air. Scavenging is carried out in its proper sequence, a rotary distribution valve being operated by the engine in order that petrol vapor should not be allowed either to pass into a cylinder during a period of flame nor to be blown out of the exhaust passage and wasted.

When perfect scavenging can be carried out without appreciable loss of power, the highest results as regards thermal effi-

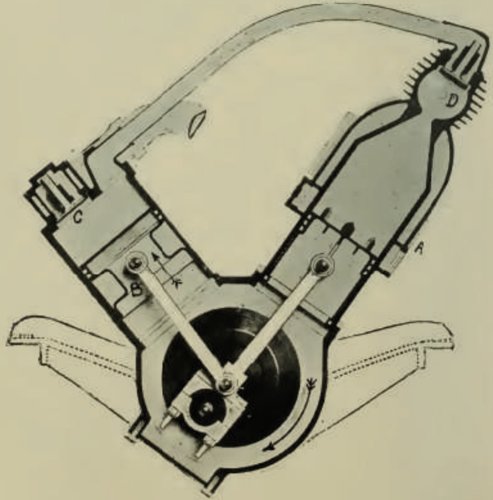


FIG. 4.—THE DOLPHIN ENGINE.