the Automatic and Semi-Automatic System will shortly be extended to Sydenham on the Illawarra lines, and to Homebush on the Main Suburban Lines.

Time and space will not permit in a paper such as this for me to deal with all the details of the various systems, but they may be briefly described as follows:—

(1) Manual System.—Where the Points, Facing Point Locks, Signals, Level Crossing Gates, and all gear connected therewith, are worked by means of rods and wires, connected to an interlocking apparatus, the levers of which are worked by manual power. (Figs. 21, 22, 23, 24, 25, 26, 27, 28.)

(2) All Electric.—Where all such movable parts are worked by electric motors, operated by minature levers, in an interlocking machine.

(3) Electro-Pneumatic.—Where all such movable parts are operated by compressed air, worked by valves operated from a set of miniature levers of a mechanically interlocked machine, combined with electric locking and releasing between the various movements. (Fig. 29.)

(4 & 5) Automatic and Semi-Automatic.—Where the Railway track is divided into sections, the signals for which are automatically put to "danger" and reverse positions electrically by the train itself. This is accomplished either by electro-pneumatic agency or by electric motors. The Semi-Automatic. —Where interlocked stations and sidings are worked by signalmen, and where both systems, automatic and humanly operated, working is in use.

(6) Lock and Block.—Where, by means of electric reversers, starting signals are put to "danger" by the action of the train passing over treadles, or other contrivances placed near the signals, and which cannot be lowered again to admit another following train until the first train has entered and cleared the next section. (Fig. 30.)

(7) Hydraulic.—Where the points and signals are worked by hydraulic pressure (water or glycerine), carried in pipes, the whole being operated by miniature levers in a mechanically locked apparatus.

(8) Electro-Mechanical.—Where points are worked mechanically by rods and cranks, and the signals (Fig. 31) electrically, by a mechanically locked apparatus. (Fig. 32.) This system is now universally adopted on the Sydney and Adelaide Tramways, the Mother Colony being the first to introduce the principle, together with the elevated signal-boxes now to be seen in the Sydney streets. At first the signals were Mechanically worked. (Fig. 33.)

METHODS OF TRAIN WORKING.

In this Colony double lines are worked mostly on the three and one wire block system (Figs. 34, 35), and single lines on

the electric train staff (Fig. 36), electric tablet (Fig. 37), or staff and ticket. The electrically controlled arrangements, such as the tablet or staff, are a great improvement on the old train staff and ticket, as, with reasonably short sections, not only can the traffic be handled more expeditiously, but as a second train cannot follow after one has been despatched and has arrived at the next blocked station, the tablet or staff cannot be released from the instrument at the despatching station until the tablet or staff carried by the preceding train has been passed through the instrument at the arrival station, thus ensuring absolute safety and preventing two trains being in one section at the same time. A most convenient arrangement (Fig. 38) for exchanging the tablets automatically is in use on the main Southern Line, and is used by the Melbourne Express Trains. By its use the tablets can be safely exchanged by a mechanical means at any speed up to 60 miles per hour.

DUPLEX LOCKING SYSTEM.

A very simple, economical, but effective device for interlocking the points of outlying sidings was invented by the author some years ago, and which was largely adopted on the New South Wales Railways, is known as the "Duplex Locking System."

~~Annette System.~~—By this method, the use of interlocked levers, lock bolts, cranks, and rodding (Fig. 39) are dispensed with, the main line and siding catch points being worked by the ordinary ball levers, whose drag rods pass through especially designed locks, released by a key.

The lock at the catch points is duplex in its action, while the one at the main line points is of the single type, similar to Annette type.

When it is required to shunt the siding, the guard takes the "train" or "electric staff," which has a key fixed in one end, and inserts the key in the upper lock, which, on being worked, releases the key kept in the lower lock. The catch points can then be closed, and the switch held in this position by a specially designed stop. The lower key is then used to release the main line points, which can be worked as described, by the ball lever.

After the shunting is completed, the main line points are again set and locked. The key is then taken back to the duplex lock, and the catch points opened. The staff can then be taken out and handed back to the driver.

It is obvious that, as the staff cannot be taken out of the Duplex Lock until the road has been properly set and locked, absolute safety is insured. The cost of this system is about

one-fourth that of the ordinary rodding method, and is eminently suitable for pioneer lines, where economy in cost of construction is indispensable.

BREAK OF GAUGE.

The unification of the railway gauges in Australia is an all important question, that will have to be faced at no distant date.

Its imperative necessity for the rapid transport of troops and munitions of war has already been emphasised by Lord Kitchener in his report to the Federal Government, and, apart from this, the commercial phase alone should urge those in authority to delay no longer.

In the author's opinion, the only practical way of carrying out the work on the lines of Victoria, South Australia, West Australia and Queensland is by the Third Rail System, and this can only be accomplished by the Mixed Gauge Compound Switches, designed and patented by Mr. W. F. B. Brennan, shown in Fig. 40.

Two very handsome models of this scheme are now with the Federal Government in Melbourne, awaiting their decision for a practical trial.

Mr. Brennan's system lends itself readily to interlocking, and is a perfectly safe and satisfactory system of switches and crossings, and would enable the changes to be effected at an enormous saving on the Departmental estimates.

GENERAL PRINCIPLES TO BE OBSERVED IN INTERLOCKING.

The first consideration must always be the "public safety," and no reasonable expense must be spared to ensure this. But on the light or pioneer lines, such as we have in our own States, which are constructed purely for the development of the country, and which, for a time, are nothing more than tramways, elaborate interlocking is unnecessary, and should only be provided when the traffic warrants it. For instance, on most pioneer lines the traffic is so small that, at the outside, three trains per week give all the carrying requirements that are needed, and this is always conducted in daylight, consequently the simplest system is all that is required, combined with safe working.

At crossing places, signals only are needed where there is an Officer in charge, and where the points can be secured by means of clips and padlocks.

The points of outlying and intermediate sidings should be secured by locks, the keys of which are attached to the electric train staff, ordinary staff, or tablet, as the case may be, as in the Annette and Duplex Locking Systems.

In the case, however, of important lines, where the traffic is not only heavy, but high speed of trains a necessity, complete installations of interlocking are imperative to provide absolute safety in working, and the economic manipulation of trains.

The question therefore to be considered is what system of interlocking is the best suited to the special conditions which exist, and the engineer whose province it is to advise on such matters should be competent not only to recommend the least expensive installation that he can, but, at the same time, provide absolute safety and efficiency. I would strongly impress on the minds of all students, both young and old, that economy should only be exercised to avoid wasteful expenditure, but never to make unsatisfactory arrangements. Another important point for the Engineer to consider is the cost of maintenance and general upkeep. This will naturally largely depend upon the stability and durability of the system in use, and also upon its constant or infrequent working, as well as its location. For instance, the wear and tear of an interlocked place on the Sydney or Newcastle Suburban Lines is much greater than on lines where the traffic is comparatively small, and, again, the action of the atmosphere varies considerably in its effect upon the gear in use, both on timber and metal.

To the lay mind the modern power plants, whether electro-pneumatic or hydraulic, undoubtedly has a fascination as an ideal system, but it has yet to be proved that the enormous expenditure involved in the construction and upkeep of any of these systems is justified, as the Manual, with its electrical adjuncts, in competent hands, provides every facility and security for the safe and economic handling of traffic, and many of the Companies in the Old World are discarding these more expensive systems in favour of the Manual type.

The general principles of all the various types are similar, but, owing to the frail and delicate parts unavoidable in power apparatus, an excessive amount of constant and unremitting attention is required to ensure their efficient working, and, consequently, the cost of maintenance is extremely heavy.

One of the most important principles for the practical Engineer to observe in carrying out new works, or the maintenance of existing plants is the standardising of all fittings and parts, so that repairs may be promptly effected when needed, to renew worn parts or those that have been damaged by accident. Unless this is strictly adhered to, endless confusion will result, and the cost of upkeep would be enormous, especially as the failures and consequent renewals may occur at places many miles distant from the source of supply. Where all parts are made to one standard pattern, no unnecessary fitting is required, and the particular articles wanted can easily be wired

for and despatched. Progress and the introduction of new principles and ideas must, of course, be considered and encouraged, but even so the Engineer must act very judiciously in his selection, and take every precaution that the safety of the travelling public is not jeopardised by his action, or the standardisation of the gear materially interfered with.

Whichever system is adopted, the visible appearance of the signals is the same, its method of operation being practically the only difference. With power types the points and signals are operated either by compressed air or by electro-magnets or motors, or hydraulics, the mechanical connections for the points and signals varying in matters of detail.

Each particular one has its advocates, and while no doubt each possesses advantages in some respects, still it is a question for grave and careful consideration by railway managers as to which system will be most suited to their own conditions. It is purely a question of administration and of commercial adaptability to suit the circumstances of their own particular railways.

Undoubtedly the ordinary Manual is the simplest and cheapest to instal and maintain, and is equally suitable for track working, but other conditions may, of course, have to be considered.

I have endeavoured, as far as time will permit, to explain in general terms what is involved in the signalling and interlocking as applied to railways. I will now pass on to the qualifications of an Engineer to design and carry out such work. They are manifold in the extreme.

QUALIFACTIONS OF AN ENGINEER.

He is the connecting link between the constructors of the road and the traffic people, who arrange for the actual working of the trains from place to place. He should be familiar with the details of Locomotive and Carriage Rolling Stock Construction.

To be worthy of his responsible duties, he should have a thorough knowledge of permanent way and the details of switch and crossing construction, as well as the designing of Station Yards and Junctions and their location. He should have a good general knowledge of the principles, rules and regulations connected with traffic working, including Block Systems, Electric Staff, Tablet, Staff and Ticket, and all methods of working single and double line traffic.

He should be a thoroughly competent mechanical Engineer, and should also be capable of designing bridges, girders, and other similar structures.

Since interlocking is not a separate and distinct branch of engineering, but embraces nearly all phases of the science, the successful Interlocking Engineer must be a good all round man, and, furthermore, it is important that all students desiring to adopt engineering as a profession should make Railway Signalling and Interlocking a part of their curriculum, as without such knowledge they would be incapable of designing the layout of any station yards or sidings, whether for the Government or for private owners, besides which, as already explained, so many branches of the profession are comprised in this designation.

This system has been much appreciated by the University Senate in Melbourne, where the Department of Engineering has included Railway Working in its curriculum for the last 20 years. All Cadets in the Railway service, moreover, have to go through their University Course before being approved as Engineers.

Of course, there is no "Royal Road," but I should think that, with the education afforded by the Engineering School of the University of Sydney, coupled with the training afforded by such an establishment as the existing Signalling Branch, in its shops and outside, such as has been the case with two gentlemen of your body (Messrs. G. E. Hall and G. A. Whitfeld, *now B's.E.*), that with further practical experience good Interlocking Engineers could be trained.

In conclusion, I would strongly urge any young man among the Undergraduates of this great University who contemplates adopting the Profession of an Engineer, to make the Principles of Railway Signalling and Interlocking a part of his studies, so that when the opportunity arises for the appointment on any railway of a competent engineer, the successful applicant may thoroughly understand all branches of his profession, and not be placed in the invidious position of having to rely on others for information.

While learning a profession or a trade, never be above asking the humblest man, or even boy, the why and wherefore. You can always learn something each hour of your life, and eventually you will find, like the author, after over 40 years' experience, that the time will come when you will have to acknowledge with all humility how little you do know after all.

Before closing, I would like to tell my engineer friends of matured experience that I consider it our duty to impart as much of our experience to the younger members of the profession, and to give them all assistance and encouragement, in order that they may become not only skilled engineers, but of greater service to the world and its advancement than their predecessors have been, and whose places in time, as the older men pass away, they must inevitably fill.

In conclusion, Mr. President, Doctor Warren and gentlemen, allow me to thank you heartily for the honour you have conferred upon me by your presence here to-night and the patient hearing you have so kindly given me, and I venture to hope that this paper may be the humble means of encouraging the young Engineering Undergraduates of this great University to a knowledge of the all important subject of Railway Interlocking.

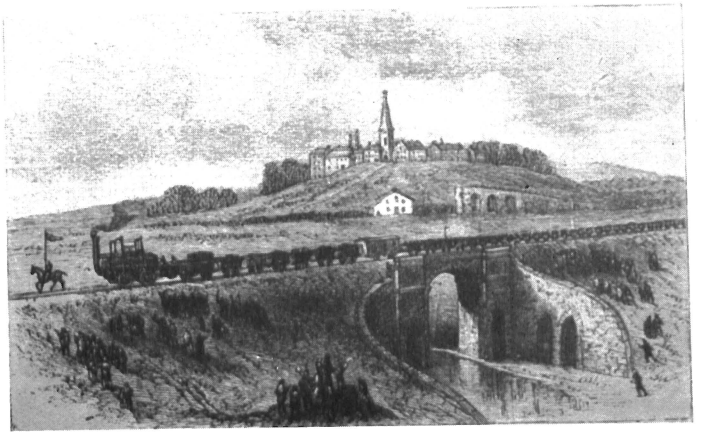
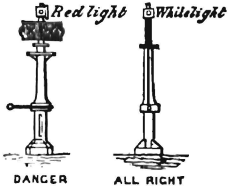
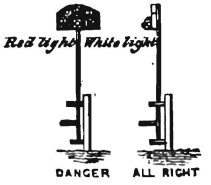


FIG. 1.

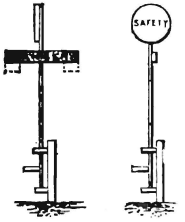
EARLY SIGNALS



Liverpool and Manchester Railway.



Grand Junction Railway.



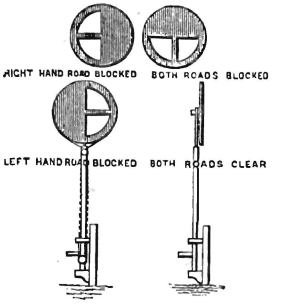
Great Western Railway.

FIG. 3.

'All right' or 'go on.' 'Caution.' 'Danger' or 'Stop.'

Hand Signals.

FIG. 2.



London and South-Western Railway Signals.

FIG 4.