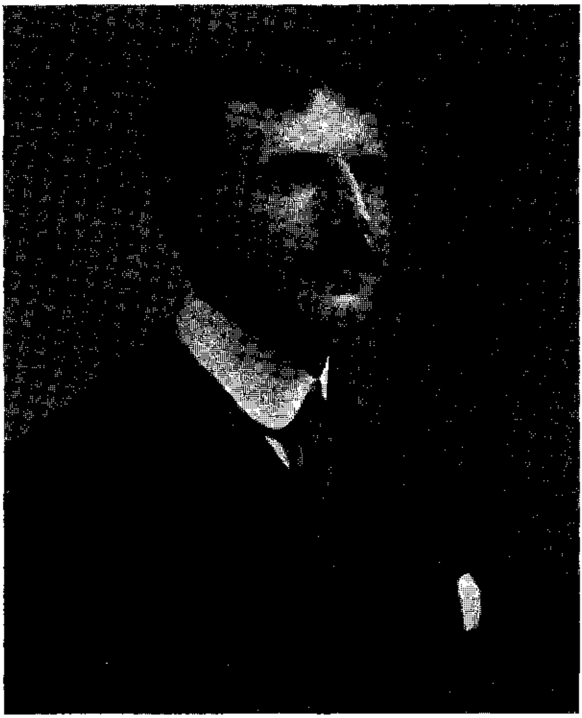
# Fifty Years of Signalling in the United States.

By A. H. RUDD (Honorary Member).

About two years ago I promised the Hon. Treasurer of the Institution that I would write something for its Journal of Proceedings giving my recollections of the many years—half a century—during which I was engaged in signal engineering in the service of some of the leading railroads of America. It has been a great pleasure to me to fulfil this promise and I trust that what follows will prove of interest to members. I am proud to have been an Honorary Member of the Institution, my membership number being 17, since February, 1913, and I have followed all its work with much attention and sympathy. The manner in which it has been carried on since the present war broke out has called forth my very warm admiration. A few words about myself may perhaps be allowed to serve as an introduction to these pages.

I was born in the village of Lakeville, near the town of Salisbury, County of Litchfield, the north-west corner town of the State of Connecticut, on March 8, 1867. Early last year Salisbury, which has about 3,300 inhabitants, appropriated $50.00 for an ambulance for your cathedral city of that name. The amount was over-subscribed and the considerable excess pooled for Litchfield County ambulances for your folks. In August 1941, the town celebrated its bi-centenary and instead of indulging in fireworks, pageants and other expensive features, sent between $2,000 and $2,500 to Salisbury, England. Now we too are in the war and are sending our boys into the armed forces. My family was English on both sides ; the Rudds (New Haven, Conn. about 1635), the Holleys (Saybrook, Conn. about 1730). I was educated in private and public schools in Lakeville and Hartford, the capital of our State, and later entered the Sheffield Scientific School, Yale University, where I graduated in June, 1886. I had been promised a situation as a draughtsman at the Baldwin Locomotive Works, Philadelphia, but orders for locomotives were few and I did not obtain it. A distant relative offered me a place however, in the Real Estate Department of the Pennsylvania Railroad in that city, where I started work in October, 1886. At college I had taken the mechanical engineering course then recently started, including about three months of civil engineering and surveying, and specialised in hydraulics. I had a little knowledge of electricity and was a fair mechanical draughtsman, though not good at freehand drawing. I have always been



MR. A. H. RUDD.
A portrait published in 1908 at the time of his election as President of the then Railway Signal Association of America, a few years after the completion of the Rudd-Rhea report, which exercised such a far reaching influence on signal engineering principles and practice in the U.S.A.

awkward with my hands, not a very good preparation for my chosen profession My first work was tracing blue prints of properties which the railroad was constantly buying and selling and later making plans from descriptions furnished by its surveyors. After a year or so, however, I wished to do something better. About that time I was offered a job as an assistant track supervisor on the Norfolk and Western RR. with headquarters at Roanoke, Virginia, but that place was nearly 500 miles from my home and I did not want to get that far away. At that time a few divisions of the Pennsylvania Railroad, hereinafter referred to as the P.RR., had " signal supervisors " (middle-aged carpenters, who knew something about pipe fitting, as a rule) and some of the young motive power men had been sent to England to learn the business. One of these had been made " Engineer of Signals " and after a year or two had been succeeded by another one, Mr. George D. Fowle. He reported to the Chief Engineer of the line, ordered materials, made plans of mechanical signals and interlockings and had one man to help him. He had no direct contact officially with any of the outside forces. He wanted a draughtsman and, although I did not know what a signal looked like, I finally got the situation on March 1, 1888, working mostly in the office until early in 1892. I then went to the New York Central & Hudson River RR. as a signal inspector, was later promoted to be the Assistant Signal Engineer but received notice on account of hard times and reduction of expenses in the spring of 1894, upon which I returned home and worked in a pocket cutlery factory which my grandfather built in 1847, bringing forgers, grinders and cutlers, who had come over from Sheffield, England, to start the job. This concern was driven out of business some years ago partly by machine forging and other mass production items, but principally by too cheap German production. It gave me employment until August, 1894, when I went to the New York, New Haven and Hartford line, where I was the foreman of electrical signals until March, 1900. In that year I was made Signal Engineer of the Delaware, Lackawanna and Western Railroad. In March, 1903, I returned to the P.RR. as Assistant Signal Engineer and was made Signal Engineer in the summer of 1907. Finally when the P.RR. and the so-called Pennsylvania Lines West were consolidated in 1920, I became Chief Signal Engineer of the entire system. (The P.RR., properly so called, had its western terminus at Pittsburg, to which city it was opened through from Philadelphia in 1852. It came to have large interests in other lines extending west thereof, the principal one being the Pittsburg, Fort Wayne and Chicago Railroad. In 1871 this line and others were brought under a common management by the incorporation of a company known as the Pennsylvania Company, to which the P.RR. interests in them were transferred, they being worked thereafter under the title of Pennsylvania Lines West, *i.e.* west of Pittsburg). I am, therefore, able to record something of the tremendous development of signalling in the U.S.A. from its primitive beginnings. A considerable portion of the early development took place on railways which in later years became parts of the P.RR. and if it may appear to be given undue prominence in these pages it is because most of my work was done there and I am especially familiar with it.

**Early Signalling in America.**

Fixed signals for handling trains were first installed in the United States on the New Castle and Frenchtown RR. (later absorbed by the P RR.) in the state of Delaware in 1832. A large white ball was raised to the top of a mast when a train left a terminal, being observed through spy glasses—when not too foggy! Similar signal balls at other stations were then raised half way. As the train passed a station the ball there was raised to the top of the mast and when it had passed the next station the ball was lowered again. A black ball was raised if trains were disabled. It was primitive but quite effective, as usually there was only one train on the road and most of the movements were made in daylight. Elsewhere, trains were run by time-tables and rules and on many railroads are so run to-day. (The expression commonly used to-day in America, " to high ball," meaning for the guard to give the starting signal to the driver, is derived from this early fixed signal system.)

On single track a train was said to be " superior " to another train by class or direction, as shown in the time table. Usually trains running from south to north, or west to east were considered as being superior to trains of the same class running in the opposite direction. Passenger trains were usually designated as first class and there were frequently several other classes. On two or more tracks, trains were superior by class. All inferior trains had to clear the main lines a designated number of minutes before a superior train was due. Until the telegraph was adopted if any superior train was delayed it was just too bad for it, or for others of inferior class or direction. Flagging ahead or behind had to be resorted to and in those days flagging was flagging ! With the advent of the telegraph, train orders were provided for and a train became superior to another train by right, class or direction. (The first American telegraphic train order is always considered to have been sent in May, 1851, by the then General Superintendent of the Erie Railroad, Charles Minot, from a station on that line named Turner. It is now known as Harriman and there is a monument there commemorating the event, erected in 1912). Right was conferred by train orders, class and direction by time table. Right was superior to class or direction. Direction was superior as between trains of the same class, on single track. On double or more tracks, right or class gave superiority. Superiority by direction was, of course, eliminated. On some railroads the "Dutch clock" was used. As soon as a train passed, a designated employee placed in a frame the train number, date and time of day it had passed his office and following trains were spaced by a time interval. If the crew of a train saw from the " clock " that the train ahead had been gone, say, only five minutes and the rules required an interval of ten, they had to stop and wait five minutes. On one of the roads where I worked and which had a half-baked automatic signal system as an additional precaution, an agent (stationmaster) was taken ill and the Dutch clock " stopped " and showed the last train ahead as having passed the day before ! The time interval was an unsatisfactory arrangement and caused a number of bad rear end collisions. The errors made in transmitting or reading train orders caused many others, even up to very recent times. Yet others were caused by employees falling asleep. With even the best of care and most careful supervision safe railroading, as we know it to-day, was a bright ideal, constantly to be aimed at but frequently unattained. In 1863-4 the Philadelphia and Trenton line (later part of the P.RR.) installed the first manual block system in America, between New York and Trenton in 1870. One-arm semaphore signals, operated by block operators stationed along the line spaced the trains not by an unreliable time interval but by actual fixed minimum distances. In 1868 the P.RR. protected some of its drawbridges with what were called " smashboards," located at some distance from the bridges, mounted on a frame over the track, and hanging down so they would be hit by a train passing them when the bridge was open. This was considered a safer device than a derailer, which might throw the train down a bank. The first interlocking frame in America was installed in 1870 at " Top of Hill," a junction in Trenton, New Jersey, on the old Camden and Amboy

Division, soon after a part of the P.RR. It was of course a mechanical machine containing, I think, 16 levers and was purchased from Saxby & Farmer of England, who sent a foreman over to install it. I once had the contract and other relevant papers, but turned them over to the P.RR.'s historical library. One-arm signals, lower right-hand quadrant, were provided for movements with traffic, pot (ground disc) signals for slow and reverse movements and detector bars rising on the gauge side of the rail. The machine was in existence a few years ago and I think may still be seen in a museum. The second such frame was installed at Newark Junction, P.RR., in February 1875, and was also imported from England. In 1875 the New York Central began to install the Toucey and Buchanan frame, so named from two of its officers who, I believe, invented it.

**Beginnings of Automatic Signalling.**

The first open track circuit in America was installed by Robinson and Pope in 1870 at Kinzua, Pennsylvania, on the Western New York & Pennsylvania RR. (afterwards P.RR.) The signals were normally clear. When a train entered an insulated section the wheels and axles closed the circuit between the two rails and the relay thus energised forced the signal to the stop position. The track circuit was very short and the signal was cleared by the operation of a track instrument depressed by the wheels. Obviously, any break in the electrical connections allowed the signal to remain clear, but the track circuit was actually opened during some part of the operation.

Dr. William Robinson, after much work, installed the first closed track circuit system at Irvineton, Pennsylvania, on the Philadelphia & Erie RR. (afterwards P.RR.) in 1872. A signal was normally clear when the track it referred to was unoccupied. When a train entered the block section, the wheels and axles shunted the current away from the relay and put the signal at stop. At no time was the track circuit opened by a train, but any breakages of connections would do so. The first scheme was the better in theory; the second scheme worked better. It is the basis of all our improved signal systems in the United States and Canada to-day. The invention was slow in securing adoption, but quite a celebration was staged on its fiftieth anniversary. Prior to this invention automatic signals had been installed operated by track instruments—called treadles in Great Britain—

of various kinds. The first was a revolving disc operated by clockwork and a weight at Meriden, Connecticut, New York, New Haven and Hartford RR. in 1866 or 1867; it was invented by Wm. P. Hall. It was wound up once a week by the section foreman. As a safeguard to prevent it from sticking in the clear position, a circuit breaker was installed, so that when the operating weight had nearly reached its lower limit the signal assumed the stop position and would not operate. The signal was normally clear. When a train actuated the track instrument (trip) the hold-clear circuit opened and a revolving pawl moved one notch. The signal thereupon turned to the stop position. When the train actuated the releasing trip further along the line the circuit was closed, the signal made another quarter turn to the clear position, parallel with the track. It was an ingenious and simple device and I had charge of its maintenance from 1894 to 1900, while engaged on the New Haven line, with practically the apparatus as it had been installed 33 years before. These revolving signals were subject to wind pressure and high gales sometimes prevented them from turning. At a much later date, this railway installed them on the normal clear principle, with a "setting" section extending five or six hundred feet in rear. An engineman was required to see a signal change from proceed to stop ahead of him before accepting it. If it failed to turn he was required to stop as quickly as he could! To avoid the wind pressure trouble the Hall "banjo signal" was invented. This consisted of a red silk disc about two feet in diameter enclosed in a wooden case with glass front and back and a lamp mounted behind the back glass. The disc was raised to disappear within the case by a Z-magnet movement, similar to that used in banner signals in England to-day. When energy was cut off the red disc dropped by gravity. Its absence before the rear glass covered opening indicated clear. At first it was operated normally clear, but it had such defects that it was later provided with an approach clearing circuit and operated on the normal danger principle. It was a difficult signal to maintain properly. Entrance openings for the insulated wires were not sealed and the cases were not airtight. I maintained these signals on the New Haven from 1894 to 1900. The silk discs were eventually changed to bunting and were stretched across a light circular steel frame. Once I opened the case of a signal which would not clear and was met by a cloud of wasps which had nested there and whose weight, as they perched on the disc, prevented it from rising. The situation was difficult as I was about fifteen feet from the ground and the insects were persistent! Frequently the dampness absorbed by the cloth during rain storms would hold the disc down. If counterweights were adjusted to enable it to clear, a nice spell of sunshine would dry it out and give us a false clear. I once saw a signal showing clear when I knew a switch—that is, a pair of points—ahead was open. I went back and found that when the signal had been cleared previously, a large black spider had been sitting on the armature and had got crushed between it and the pole piece. As he dried out he exuded a muscilagenous paste which held the signal off. All the batteries were of the blue stone or gravity battery type, with a copper plate at the bottom and zinc circular disc at the top. They were filled with "blue stone" copper sulphate, blue vitriol solution, and were really something to maintain!

**Early Work on the Pennsylvania Railroad.**

By the year 1888 a number of mechanical interlockings had been installed on the P.RR., and the manual block system was in use on several of the main lines. We used to print all requisitions for material by hand and copy them, using a letter press, with wet blotting pads in a requisition book. The first thing a green hand did, of course, was to wet the blotters too much! I mastered that. Our signal masts, or posts as they are known in England, were of pine, long and heavy. We had to re-design them to cut the cost. At that time we copied English practices in almost every respect. The leaders in manufacturing were largely English. The English roads ran left-handed, following their highway driving practice. The American roads adopted the opposite practice, following their highway driving practice. The English signal arms pointed to the left and on some railways the driver stood on the left. The American engineman sat on the right and the arms pointed to the right. This was quite a difference and one we should not have made. (Only a very few lines in America ever adopted left-hand running. The principal ones were the Lake Shore and Michigan Southern Railroad, now part of the New York Central System, and the Chicago and North Western, which has always called itself a railway, not a railroad. The latter's trains still run left-handed but on the former the working was reversed about 35 years ago). Our lines were largely single and there was relatively little double track. The signals were placed on the right of the track. Had we left the arms pointing to the left, with the masts at clearance distance from the rolling stock with the arms above it, we should have been able to narrow the right-of-way and the telegraph—and later telephone—lines could have been placed nearer to the track without interfering with the movement of the signal arms. In another point we differed. Instead of using gantries or brackets, our practice was to place all the arms governing a track and those diverging therefrom on one mast—as at first was done in England—the top arm applying to the diverging route farthest to the right, so that in some cases such an arm led to the main through route and in other cases the second, third or fourth arm might so lead. There were even some five-arm signals, although most of these latter were placed on bridges, but with, I think, 7-ft. spacing (at any rate 6-ft. 6-in.) between the arms, with masts set 6 or 8-ft. in the ground. The lengths of the sticks required for the masts necessitated undue expenditure.

About this time we began to have trouble with our " signalling to the right." We had a bad accident on the Pittsburg Division. At one interlocking the top arm governed to a high speed main track and at another it governed to a siding and into a turntable. These signals were 30 or 40 miles apart, but the engineman had a mental kink—the signals did not check him—and ran at high speed into the turntable and stopped. The train went on. I am remembering without notes and do not recollect how many were killed and injured, but it was a nasty accident. Mr. Fowle then wanted to change our signalling and have the top arm read everywhere to the high speed route. All our locking frames were of the old Saxby and Farmer type with " flop " locking, however, and with five arms we had to use two, and in a few cases three, levers for one signal. We had to try other methods and we experimented with the so-called " emphasised arm."

The arm governing the main through route was made longer than the others and was equipped with a diamond shaped piece of wood near its outer end to make it more prominent. There was no provision for this " emphasis " in the coloured light night signals. This arrangement served its purpose in a way but was far from ideal. At this time Mr. Fowle's assistant was placed in charge of construction work for the Union Switch & Signal Co. and I started working nights again, practising on working out locking and making dog sheets—that is, locking diagrams—and was sent to outlying signal towers (boxes) to see how the locking operated. Signalmen were forbidden to step on the rockers. They were instructed that they must use their hands to raise the catch handles. I remember one of them told me he was the only man on the line who obeyed the rule—he had only one leg! An Englishman, John T. Hambay, did much in the development work for the U.S. & S. Co. He invented in 1889 the " tongue " locking—later generally called the " improved Saxby and Farmer "—which gradually replaced the flop or gridiron locking and was a godsend in big plants. (This locking became well-known in England when electro-pneumatic power frames were introduced there).

Our facing point locks were located on the ties—the sleepers—between the rails. Many were torn out by dragging equipment so we placed them outside the rails and set them in the ties; the next move was to place the lock bars outside also, and Hambay invented an inclined pattern which rose inwardly under the tread instead of under the flange. This could be mounted higher than the inside bar, a great advantage during the prevalence of snow, ice and freezing weather. Mr. Fowle got another man, Mr. W. J. Gillingham, afterwards Signal Engineer of the Illinois Central, from the Locomotive Department, but about this time a business slump set in. We had almost nothing to do and I was afraid I would have to leave. Six assistant track—permanent way—supervisors had taken a course in signalling. One of them named A. T. Dice, had been called to the New York Central, where there had been a succession of accidents, to supervise the installing of signals on that line. I had been sent out with him to install some signals at the end of a double track about 12 miles from Philadelphia. He constantly consulted with Mr. Fowle and one day I asked him if he wanted a good man to help him. As a result I went to the New York Central in March, 1892, in supervisory charge of installation work being done by contractors between Yonkers and Albany, covering about 128 miles of double track, with a number of passing sidings on the outside of the main lines. The heavy suburban traffic was already protected by lock-and-block between New York and Yonkers, a distance of 14½ miles, but north of there, on the main route up the Hudson River to Albany and thence west to Chicago, trains were operated on the time interval and " protected " by flagmen who went back if a train was delayed. There were practically no interlockings. Some of the curves were protected by station watchmen operating so-called " dead man's hands," semaphores pointing to the *left* and operated by rope or wire. They were normally clear but went to horizontal when the rope or wire was slacked off by revolving a wheel, and were pulled down again after a train had passed by hauling in the one wire. There was a virgin field to work in and the signal people made the decisions. All the passing sidings were interlocked and nearly all the outlying switches. The signal arms were made to point to the right. The home arms had two positions, horizontal, with red light, for stop; 60 to 80 deg. inclined downwards, with white light, for clear. They were painted red with a white stripe. Distant signals had green fishtail arms with a white stripe and in the horizontal caution position showed a green light. Inclined downwards they showed a white light for clear. Block stations were equipped with a home and a distant signal in each direction. Typical interlockings had a second home signal—an advance signal—located in advance of the interlocking, which governed the block section to the next block station or interlocking. Distant signals were located about 1,800-ft. from their home signals and were wire pulled, with front and back wires. Most of the home signals were operated in the same way, but a few were pipe connected. Dwarf signals for reverse and other slow speed moves out of sidings were short arm semaphores, with red and white lights.

After our experience on the P.RR., Mr. Dice, who later became the General Manager and finally President of the Philadelphia and Reading Railroad, one of our big anthracite lines, decided that where arms were mounted one above the other the top arm should govern the straight through main line route, the second arm into passing siding and the third to all other routes, if any. The distant signal was controlled by all the home signals in the route, but a home signal gave no indication of the condition of the next signal in advance. Everything was mechanically operated, but there was some track circuit control added, a big step forward. At the block offices a switch cabinet, as it was called, was installed for each track. A short track circuit was installed in advance of the home signal, which was, as we termed it, " slotted." A device was placed on the signal with a magnet coil. When the magnet was closed the operating rod of the signal was intact, when the magnet was de-energised, due to the track circuit being shunted or open, the operating connection was broken and the signal assumed the stop position regardless of the position of the operating lever. This would be called in Great Britain an electrical replacer. When a train passed a block station the signalman advised the signalman or operator at the next one and he in turn asked the next man for an unlock. That man then pushed a plunger which unlocked the instrument in the tower in the rear asking for the unlock, and the man there then cleared his signals. When the train passed it set the signal at stop and this signalman had to put his home signal lever normal while the train was actually passing his signal, or he would be locked at stop for the next train. After the lapse of fifty years I cannot remember whether at interlockings there was a track circuit for the home signal governing over the points as well as for the advance signal governing into the block section, but the home signal had certainly to be set at stop and the lever put normal before the operator could "plunge" to unlock the advance signal in the rear. It was a modification of the Sykes system, and with the added track circuit check we thought we were just about right. We installed about a hundred stations in a little over a year. Morse telegraph operators were on duty at the interlockings and "towermen"—communicating by bell code—at intermediate points. After the work was installed I was placed in charge of the maintenance, the maintainers and the towermen. The operators reported to the division operator. I used to patrol the track on foot a good deal. One day I was hidden by a passing train from a towerman who, as soon as it had passed, ran down the outside stairs to the bottom storey. I saw him through the window doing something to the battery. I asked him what he had done, and he, of course, said he had done nothing, but finally he admitted that he was busy at something else and had not put his signal lever back while the train was on the track circuit and was left locked up. He therefore pulled a pencil zinc out of the battery, opened the circuit, ran upstairs and put his lever back, went down again and closed the circuit. Another foolproof device gone wrong! You couldn't beat those fellows; they should have been in the secret service!

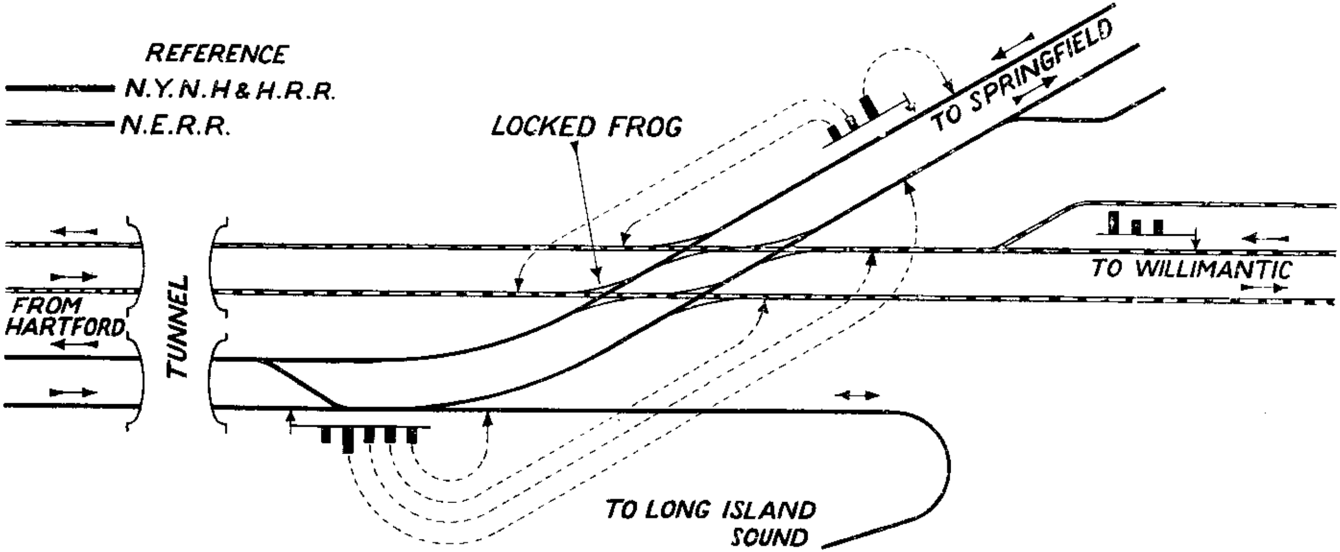
The line was equipped with red lights on switch targets—point indicators—showing when a switch was open. The enginemen were much worried by red lights for stop in the dwarf signals, and after many experiments we adopted purple ones. The apparatus operated quite well on the whole. We had a lot of trouble keeping the " slots "—replacers—on home signals adjusted. Track circuit equipment was rather primitive. Hot days and cold nights made wire connected distant signals hard to adjust and in some cases "gainstrokes" were used. Instead of attaching the wire to the lever, it was fastened to the floor and run over a pulley on the lever, doubling the stroke and, incidentally, the counterweighting on the lever tail. If, as sometimes happened, a weight fell off as a lever was being pulled the leverman got a jolt. As he did if one of the wires broke. We had to do a lot of efficiency checking, both of train crews and signalmen. We had a " pony engine " as it was called, a beauty, with five or six seats built over the boiler and on moonlight nights the trip up and down the Hudson River—the Rhine of America—was glorious. One night we stopped at a tower where the lights were dark and the signals clear. We crept up the stairs to find the leverman asleep. As we opened the door he jumped up and put his levers normal. The Superintendent asked what the matter was. The man replied, " I have not done anything wrong ; there was a horse in the block." Nightmare scored for him. We had many funny experiences. A man named Beezer had invented, among other things, a peculiar kind of non-wearing locking dog for interlocking frames. He had one at Yonkers, New York, and we had to add two or three crossovers there. After weeks of trial he was ready and on the appointed day appeared in a top hat and frock coat with his man Burley to do the work. He took the locking out and then could not get it back. Meanwhile we connected up the points and f.p. locks and found that the foreman had set all the cranks wrong, so that when we started to test them the lock bars tried to go down instead of up ! It was about a two days and nights mess and I stayed with it.

If the locking jammed or broke, or a signal could not be cleared a leverman was permitted to issue a " clearance card " to a train, after seeing that everything was right. Our point levers were painted black, our f.p. lock levers blue, signal levers being red or green. At a point called Crawbuckie Switches, north of Sing Sing, where the New York State prison was located, passing sidings were installed about a mile long outside the double track with a trailing crossover between the main tracks. At the exit ends of the passing sidings were derailers. The main track advance signals were outside the passing sidings to save expense and the exit ends of the sidings governed by dwarf signals. An inexperienced signalman had a train coming from the south and pulled the black point lever opening the points to the passing siding in mistake for the blue lock lever and of course could not get his home signal. He issued a card, cleared his advance signal, signalled " train on main track " to the next signalman, who cleared his advance, home and distant signals for that track. The engineman was moving so slowly that he did not notice he had gone over the turnout. He was making about 20 m.p.h. when he went over the derailer into a marsh. It took two or three days to clear up the wreckage. Early in 1894, a panic to economise hit us and my chief sent for me and said he was going to the Philadelphia and Reading and I would have to report to the Division Superintendent. The latter gave me thirty days' notice !

In the August I got a job as Foreman of Electrical Signals on the New York, New Haven and Hartford. The division was 26 miles to Springfield on the north and 36 miles to New Haven on the south, all double track except a gauntlet on the bridge over the Connecticut River, about half-way between Hartford and Springfield. The interlocking at Springfield was operated and maintained by the Boston & Albany line. There was a unique one at Hartford, a level crossing with the New York and New England Railroad, which I maintained, and two at New Haven, maintained by the Shore Line division of our road. The division was operated by time table and train orders, with the added protection of Hall disc signals and " Dutch clocks." The disc signals were nearly all spacing signals, or installed for protection on curves, and were normally clear. My deceased predecessor had been connected with the Hall Signal Co., which had installed the signals, and there were no circuit plans of any kind available. I asked that company for theirs and they sent me one " typical." I borrowed a bright boy from the permanent way department and we traced out every wire on the division. I found that each signal and track circuit had a separate battery. The open circuits required constant attention and failures were frequent. An average of five or more failures per signal annually ; in fact during the first few months the average was six per year. Eventually I had made plans of each location and then I set to work. I combined all the separate batteries at a given location, thereby keeping them all fresh. After each storm many signals would fail to clear on account of the moisture absorbed by the discs, the signal heads not being tight. This we tried to remedy. We had six maintainer sections and the maintainers took care of the batteries. We had a " floating " gang of three or four, who took care of big repairs but we had no money. Many of the signals (including a lot of crossing bells at highways) were operated by treadle " trips," which required the co-operation of the permanent way department to keep them at the proper elevation to be hit by the wheels. The failures were so numerous that the Superintendent accused me of inefficiency, saying there had been none until I took charge. I pointed out that he had previously only heard of those the drivers chose to report and that even now they were only doing so when delayed, and that except where he could see the line from his office they were ignoring the signals. He then accused me of making false statements and I said " Will you come out on the road some day with me, hide in the bushes, let me set a signal at stop and prove it ? " He consented to do this and we went then and there to a point about ten miles from Hartford where I set both north and south bound signals at stop. We saw the Boston express and a local passenger run by, merely giving the prescribed two blast acknowledgment whistle signal, without even a pretence at slowing down. On returning he proposed to suspend the men but I induced him not to do so, as that would convict the management of having been asleep before, or having known that the signals were being treated as a joke. I suggested he should call in eight or ten drivers and tell them that in future they must stop and report signals, or disciplinary action would follow, as from a certain date. I told him I must have his support if I was to get the signals operating satisfactorily and I persuaded him to adopt the course I proposed. I had told my men weeks before that they would not be disciplined for failures but that they would be for not reporting ; that even a false clear failure would be excused if the cause of it were legitimate. If such a failure were concealed, however, it would mean dismissal. When I left the line six years after I started with it failures per signal had fallen to 0·3 per signal per year, as against 5·0 to 6·0, which was still a high figure, but was some improvement ! In place of the wheel machine previously mentioned—a beautiful piece of work—we installed a 56-lever National type frame machine with vertical locking in three layers. If anything broke in the central layer, one of the outer layers had to be removed and this happened. The National machine had a rocker action and Stevens tappet locking. At this point the double track of the New Haven crossed the double track of the New England. The signals were normally clear for the New Haven. When a New England RR. train approached, a man at each end of a cylinder 12 or 14-ft. long started " cranking " the machine with vertically rotating levers. The distant signals on the New Haven gradually went from clear to caution, then the home signals from clear to stop, then the New Haven derailers began to open and the New England to close, then the New England home signals—all signals were one arm—began to clear and after they were clear the distant signals cleared, so that finally the route was set and signalled. In the same signal box was a small Saxby and Farmer machine which controlled points leading from one of the outside New Haven tracks to a branch which, after a 180-deg. curve, ran south to Long Island Sound. As I remember it, it took between 3 to 4 minutes to change the routes. On the first shift a cripple and a young man did the work. This was the best shift of the three. The old man knew his job ; he let his helper, who grew to be a very dear friend of mine and retired very lately, do most of the work. As business and speeds increased, we needed more interchange facilities so that instead of straight crossings, it was felt necessary to install slip points and movable point frogs at 4 points (see sketch on page 59). Plans were very carefully worked out, foundations installed with cranks and pipe connections. The entire track arrangement was assembled to provide a " killer " in engineering under traffic. Hand signals were to be given until the change was made. As I remember it, we cut loose at noon Saturday and planned to be finished at noon Sunday. The tracks were ripped out at the appointed time, the slips and movable point frogs already assembled were laid in and proved to be about 18-in. too far south. Mass production gone wrong ! The permanent way men would not change. Every foundation for crank and compensator set in concrete was wrong and the track was, of course, right ! I had been to the office early and got to the battlefront about 10 a.m. The old machine had been broken with hammers, the new machine in a new brick cabin was all set up and the rodding had nowhere to go. The foreman, who was 86 on June 17, 1942, was nearly crazy and so was everyone else. By late Saturday evening we had all the important points connected up, but no lock bars. The high signals were operative. I personally set all routes. Between 2.0 a.m. and 3.0 a.m. Sunday I slept on the operator's telegraph table. I kept it up Sunday, slept in the same place for an hour early on the Monday and at 4.0 p.m. Monday I turned it over to the operators telling them when a route was set and signals cleared to leave them cleared until entire train had cleared the interlocking, as only a few lock bars were working. I went on the job again on the Tuesday at about 10.0 a.m. and put in another stretch of 30 hours. We made the change with not a wheel off.

The gauntlet bridge over the Connecticut River was "protected" by home signals located about a quarter of a mile on each side, track circuited through so that neither could be cleared if the track between were occupied. Close to the ends of the bridge were two other signals operated from a 2-in. long hand switch in the baggageroom of the station at Warehouse Point operated by the station attendant to give the signal to whichever train (north or south) was first due. It was slow speed territory. Of course, one of the two signals for the same direction might be at stop and the other clear. I wanted to move the outside signals back, make them distant signals for the two bridge signals and track circuit these signals across the bridge, giving simple protection without confusion of indications, but my chief said they had worked for years—which was true—and I was to leave things as they were. As my luck would have it, two or three weeks later he sent for me and asked me what I had been doing with the Warehouse Point signals. I said I had done nothing and he once more accused me of telling a falsehood. I must explain that the two New York and Boston fliers passed each other at a big tree on the double track six or eight miles from Hartford and hardly varied a thousand feet, night after night. The night before the express from Boston was late and the two trains approached the bridge at the same time. Both got clear signals and stopped head on on the bridge about 200-ft. apart. When my chief and I arrived we found the maintainer at the station and the chief asked him what I—whom he politely designated "a young fool"—had been doing to the apparatus, only to learn that no changes whatever had been made. The night baggageman then came forward and explained that he had knocked the little wall switch, which had been set to give the late running train preference, with a trunk he was moving and reversed the signals. Luckily the reversal was seen by the Boston-New York train, which commenced stopping. The baggageman, an old timer on the line, was shaking all over. Later in the day the chief sent for me and admitted he had not found me out in any untruth, telling me to do anything I thought necessary to make the bridge safe but saying he would hold me responsible if anything amiss occurred. The signals were then re-arranged. Meanwhile we were gradually installing track circuits in place of treadles, combining batteries and improving the maintenance.

We maintained the "banjos" from New Haven to Shoreline Junction and the Shoreline Division maintained the interlockings and then we maintained those signals north. As ours was a more important line at the time and as we had the new interlocking at Hartford to maintain, it was decided we should take over the Shoreline interlocking, giving us a continuous line to maintain. My chief thought some changes would be advantageous but I did not agree with him, sending him a letter, of which I took a copy home, in which I gave my reasons. He instructed me to proceed, however, which I did. A signalman made a mistake, and routed two trains head on to the same track, where they stopped short only 50-ft. apart. When my chief raised the question with me and I pointed out I had made the changes he ordered, of which I disapproved, an angry dispute followed and he threatened to discharge me, but after I had said I would appeal to the General Superintendent and show him the correspondence, it terminated satisfactorily. A year or two later one evening a tappet broke in the middle layer of the interlocking in the Hartford frame, as a northbound New England train was passing over the plant. The frogs and slips on this line were locked (see sketch) and the southbound New Haven route tied up. Several trains, including the Boston-New York express were held up north of the plant. After a discussion with the yardmaster of the New England line who was in the signal box, I told the conductor of the first New Haven train to take the top high signal, go along the New England track clear of the dwarf signal, back up on the dwarf beyond the New England home signal, take any arm he got and go ahead. He said an order from the Superintendent was needed, and on my trying to telephone to that official I learned he was at the theatre but they were calling him up. However, I said I had his orders and the movement could be made, Later a message came to say they were to do what I told them, but everyone thought I was heading for trouble, all the same. The trains were got through successfully on my instructions and the next day the Superintendent sent for




Crossing Junction at Hartford, Connecticut, between the New York, New Haven and Hartford and New England Railroads, the scene of the incidents described on pages 56 and 58 of Mr. A. H. Rudd's narrative.

me. He said he understood I had made myself the Superintendent on the previous evening and I told him I had, as the night Superintendent had not known what to do. My chief replied that that person had not appointed himself as Superintendent, but I asked whether, if he himself had dropped dead, the trains would have had to wait until a new officer had been designated to supersede him. Upon that he congratulated me and we got on well afterwards. I may just mention here that years before Mr. E. C. Carter, then Chief Engineer of the Chicago & North Western, who dominated its signal policy, had installed the green light for clear and a green and a red light side by side from one lamp, the green being reflected, for caution, with of course red for stop. He used Hall disc signals as automatic block signals and semaphores as interlocking signals, and was much ahead of his time. The New Haven had had a number of bad accidents and finally at Readville, Massachusetts, a home signal light was out and a white light on a raised highway crossing barrier was mistaken for it, causing a terrific accident. After much experimenting the " Nels yellow " was adopted as the caution signal, with green for clear. This meant changing most spectacle castings and adding attachments to the disc signals, bringing difficulties with counterweighting, etc.

As a result of an article I wrote in the technical press I was offered in February, 1900, a post on the Delaware Lackawanna and Western Railroad and accepted it, but before I left the New Haven I had the Valley Division added to my territory and was made Signal Engineer of it. My Chief endeavoured to get an increase in salary for me and keep me, but there was already a Signal Engineer for the big New York Division and his jurisdiction was, quite properly, extended to cover all territory west of New London.

**Work on the Delaware Lackawanna and Western.**

I became Signal Engineer of the D.L. & W.RR. on April 1, 1900. This line, mostly double track, ran from Hoboken, on New York harbour, where there were three lines of passenger ferries to that city, to Buffalo, New York, with branches from Binghampton to Syracuse and Utica. The three-track suburban section as far as Dover, New Jersey, had Hall disc signals with a number of interlockings, but west of Dover it was virgin field. On the New Haven at junctions they had " signalled to the right " with emphasised blade. At Hartford the third blade out of the four was for the main line and was extra long, but the light was the same length as the others. On the Lackawanna the top arm governed straight through, the second arm to any running diversion and a dwarf signal at the foot of the high masts to all diverging routes. On the three-track line the signals for the middle track were mounted on bridges and, as all movements from the middle track to main were at medium speed with traffic, had no dwarf signals at the foot of them. Green was used for caution and white for clear. Two contractors were then making offers for the work. The Union Switch & Signal Co. recommended normal clear working for the automatics, and the Hall Signal Co. normal danger. (As the latter company is extinct and most of its old officers dead, the facts may now be told just to show that no man is perfect and a great many men far from it). I recommended normal clear and most of my recommendations were accepted. Up to this time I had been a " copy cat," believing other and older people knew more ; but from now on I thought things out and concluded I knew as much as a lot of them. I found that the existing disc automatic signals, red disc and white background, had overlaps, each signal indicating red and being controlled to that condition until the rear of the train that set it passed the next signal ahead and some distance beyond it, after which it continued to show red until a following train entered what was called a clearing section, extending several hundred or thousand feet in rear of it, the distance being determined by sight, braking distance, etc. There were few distant signals. The result was that braking distances were longer than necessary, but there was a saving in the number of signals and in the primary battery. There was, however, an excess of line wires run in wooden trunking along the track and a false sense of security was obtained by men riding trains and watching the signal performance from the rear. It was an easy job to cut over to normal clear by closing the clearing section wires at each signal and then taking out these wires. When we did this one signal stayed clear with a train in the block section. Two weeks before a lightning storm had fused the controlling relay closed, but as soon as the rear of the train passed the signal the clearing section relay, which was de-energised as the train approached the signal, picked up, opening its back (clearing) contact and keeping the signal at stop. A following train approaching the signal would thus clear it although there might be another train just ahead in the section " protected " by this signal ! That one incident was enough to destroy confidence. The contractors had installed these signals (on a cost plus basis) at normal danger, receiving a commission on all materials they did not make and had made great claims on the normal danger savings in battery, etc. When we opened the trunking to take out the dead wire, we found that instead of there being a pair of wires to the clearing relay the wires had been run back and forth two and sometimes three or four times, thus increasing the purchase of wire four, six or eight times, and also increasing the amount of battery cells required to push the current through. The explanation was they were spare wires to be used in case of emergency, but as they were the engineers on the project and had told no one of these spares it did not make a very good impression. A year later when their material man offered me a percentage on any purchases made by us the flower began to fade.

There were six or seven two track drawbridges ingeniously protected. The mechanical foreman was a fine man who retired August 1, 1942, as Signal Engineer of one of our big southern lines. The bridges revolved all the way around, so that they could follow a boat through and save all the time possible on the busy suburban lines, which at times had four trains over them in ten minutes from the ferry boats. Instead of the usual square end butt rails the ends were bevelled, the shore ends being spiked and the draw ends raised before the bridge was turned. Derailers were provided about 500-ft. from the ends of the draws, the approaches to which were on embankments, and when open would turn a train into the space between tracks instead of down the bank. Signals on both tracks had to be set at stop before any derailer could be opened on either track. Signals were mounted on bridges which supported very large squares of red board which were lowered across the tracks before the derailers could be opened. This arrangement was far better than anything I had seen anywhere before. For the new automatic work I had recommended two arm signals with red arm on top and green fishtail arm below, the latter acting as a distant signal for the top arm in advance, and no overlaps, the signals being located for the best view of approaching trains and about a mile apart. We, of course, had d.c. track circuits, and we had lots of cinders and carbon, as the line was known as the " road of anthracite." Its principal business, next to the suburban traffic, was the coal from its own mines in the Appalachians around Scranton. In many places we had to use cut sections, as we could not maintain mile long track circuits, as all the engineering had been done for single arm signals and overlaps east of Dover where my recommendations were not accepted. The management was in a hurry to get protection and contracts were signed within two weeks of my arrival, I believe. But all work west of Dover was of the home and distant type. At that time there was great agitation against trains running against red lights. With a three-arm interlocking signal a train might receive either a white light over two reds, or red, white and red, or two reds over a white, depending on its route. Believing the right thing had been done on the New York Central, we installed purple stop lights in dwarf signals instead of red and it was only a few months before we decided to adopt green for clear. I convinced the Chief Engineer that a red light should mean stop, that nothing else was necessary and that the big red signals at drawbridges should be abandoned. The Superintendent disagreed and said he would not issue such an order and the Chief Engineer advised him, with proper adjectives, that he did not care whether he did or not ; the boards would come down the next Sunday, and down they came. The General Superintendent later issued a general order substituting green for clear, after new spectacle castings had been purchased. We had a little trouble with a small gang and having to change over in one day but no accidents, though some of our men, not being as familiar with the difference between subject and object had put the roundels in so that green showed with signal horizontal and red when it was cleared ! We still, however, had trains running against red signals at interlockings. The next move was to block up the openings where red lights had been displayed in the second arm and dwarf signal under it, so that a fast through train would receive one green light, a medium speed diverging train red over green, and a low-speed diverging train green dwarf with red on top. It satisfied the theorists and objectors and worked fairly well, but at interlockings we also followed the New York Central practice of having a distant signal, a home and an advance (block) signal, the distant being held at caution if either the home or advance was at stop. One night a red home signal went out. This signal governed over a short drawbridge and a level crossing with another line on which a train was moving and, of course, the derailer was open. The engineman of our train slowed for the distant signal, rounded a curve, overlooked the home with its light out, saw the block signal green light ahead and opened up. He ran off the derailer and across the bridge on the ties, stopping a few feet short of the other train. This did not look so good, but it was felt that the scheme was better than the old one of running past a red light at each interlocking and no change was made. The system was extended over the entire line and was operated for many years without a similar accident. The P.RR. had several stretches of automatic semaphores, mostly on wooden masts, operated by compressed air cylinders electrically controlled. The up and down rods from the cylinders to the spectacle castings were, of course, exposed and in some of the sleet storms in the mountains froze clear. The Lackawanna signals had tubular steel masts and the up and down rods were inside, being operated by a d.c. motor, battery driven and located, with the electric slots controlling it, in a case on which the signal masts were mounted. We installed the signals rapidly and in the winter our troubles began. The weather is very severe in the Pocono mountains east of Scranton, 25 deg. to 30 deg. below zero Farenheit being not uncommon with very heavy gales. The days are usually much warmer than the nights. During the nights frost would form inside masts. During the day it would melt and run down the up and down rods on to the hold off coils and in the night the holding gear would freeze closed and false clear signals result. That particular winter was a hard one. One night 57 signals stuck clear, in spite of all our men being out trying to thaw the holding mechanisms. We had left train order semaphore signals in service and cabins about 5 miles apart down the mountains. We established a manual block signal system overnight without telling the enginemen, as we did not want their confidence in the automatic signals destroyed. So we held them " for orders "—which never arrived—until the preceding train had passed the next cabin. Then we put drip pans in each signal so that the water running down the up and down rods would be deflected from the hold clear mechanism. The foreman of electrical signals went crazy after three or four weeks, and died in hospital of pneumonia in less than a week. I started for his funeral and broke down at my own door. It was six weeks before I went to office and about eight before I really got into the swing again. Soon after that we had terrific storms and I was called out for day and night work on wires controlling trains through a tunnel about 1½ miles west of our big passenger terminal yards. This set me back again for a while.

In the spring of 1900 it was decided to protect the big yard at Hoboken, New Jersey, which was operated by a lot of pointsmen who gave hand signals to trains and to each other, with electro-pneumatic interlocking. The work was finished just before the Christmas of that year, but on account of the seasonal traffic rush not put in service until December 30. The yardmaster resigned because he said the yard could not be operated in that way. We had had the "levermen" practising for weeks under arrangements giving electric indications for points and signals as if they had been operating. When a train came out of the tunnel they started work. At first the trains would be in the station, unloading passengers, before the route was "set up," but they kept at it until the route was set before the train entered the interlocking area. The same practice was followed with outgoing trains. The whole job was new to all of us. The day before we opened up all functions were connected and tested out, but the circuits from the levers were kept open by inserting playing cards between the contacts on the machine, the points being operated by pushing their air valves locally by hand. Cloths were used to cover the signal blades. At one minute past noon the plant was put in service, the cloths being removed and the playing cards slipped out at noon. The change took less than a minute and everything worked perfectly, except for a few cases where contacts had been bent by withdrawing cards and had to be adjusted. There was a model over the machine showing the positions occupied by the various points and in our early practice the men watched this to see if they were operated properly. Later on this model was covered, the routes being called and set up without the men seeing them, so that they became nearly letter perfect. Several of the contractors' men who worked on the Lackawanna and several of my own men afterwards became signal engineers of big railroads. This was the only power interlocking installed on the line, but we revised old and installed new mechanical ones in a number of places and had many interesting experiences. We had a lot of trouble with "foreign current." As I have said, lots of the embankments were made of cinders or coal dust, which packed and made a fine road bed. A lot of the ballast was of the same material. A great deal of dirt jolted off the cars and much of the current leaked across the ballast. If one rail were buried more than the other and a bond wire broke, which was a frequent occurrence, the weak current from the track battery might be reversed and a false clear result, or the rail might pick up stray current from a nearby electric tramway. "Eternal vigilance" held this trouble down and we generally knew when to expect it. We had one case, however, that proved too much for us. Miles from any tramway or river we had a failure due to a broken bond wire. In our tests we disconnected the batteries entirely, stuck the wires into the ballast and got clear signals. There was electricity coming from the cinder banks. We cut the section of track into two and cleared the trouble, but I do not know to this day how the "foreign current" was generated. We used what was then known as the wireless circuit. There were polechangers on the signals with neutral-polar relays having two armatures. When a train entered the circuit the neutral armature dropped. When it passed out into the next circuit at the cut section or the next signal the polechanger shifted. When the rear of the train passed out of the circuit the neutral armature picked up, clearing the home signal, but the distant arm beneath it remained at caution until the rear of the train passed the second signal in advance. The polechanger was then reversed at the first signal in advance and this in turn operated the second armature of the first mentioned relay and cleared the distant arm. It was a very neat system but at cut sections one section of track relayed the other through a neutral-polar pole changing relay which responded to the movements of the home arm immediately ahead. We had a large number of these relays become fused during thunderstorms. Electricity in the air apparently made a condenser of the rails, like a Leyden jar, and when enough of a charge had become built up, it jumped from the magnets to the armature and thence to the adjacent (relayed) track circuit and fused the armature to the pole piece of the relay. Of course, a false clear failure resulted. When such conditions became really prevalent we did away with relaying the track and ran line wires back as a substitute for the rails. We then developed a relay with enough distance between the armature and springs attached to it, filled with insulating material to prevent the jump over. This, incidentally, caused a complete redesign of practically all future relays.

A coal miners' strike occurred while I held the office of Signal Engineer to the Lackawanna, which had more money and credit than its competitors. The President of the Company sent for his staff, myself included. The locomotive man was ordered to get his engines and coaches away from the affected district, get every engine in shape for putting it in service at short notice, then white lead and store it. All coal wagons to be treated in the same way. The Chief Engineer was to rush all his authorities and ask for more if he could handle more, while I was to rush the signal installation to the limit. " So that when the strike breaks, the others will have to fix their equipment, and we'll handle the coal," which we did. By the end of 1902 half the line was equipped with the new signals and most of the "bugs" had been killed. The performance was fair. I had always wanted to get back to my first love, the P.RR. One of my classmates had been made General Superintendent of Motive Power a few months before. My old chief, Geo. D. Fowle, had had a stroke and wanted me back, so I wrote my classmate, W. W. Atterbury, to see what he could do. In January, 1903, the latter was made General Manager of the P.RR., when I was nearly 36. The rule on that line was that no man was to be employed permanently who was over 35 on account of their pension system. The General Manager got the Board to pass a resolution authorising my appointment as Assistant Signal Engineer. (The Signal Engineer had been appointed by the General Manager and reported to the Engineer Maintenance of Way, who reported to the General Manager). The Chief Engineer of the Lackawanna offered me an increase in salary and the General Superintendent a division superintendent's job after I had finished the signal installation. " Better to be a big toad in a little pool, than a little one in a big lake." I could not resist, however, so March 14, 1903, I ended my job there and on the next day started once again on the P.RR. I had recommended my successor, but the management wanted to give him a trial first, so by mutual consent he was made ' acting ', and I ' consulting ' for a month or six weeks with afternoons and Sundays at Hoboken, which arrangement terminated at the end of April, when he was appointed Signal Engineer.

**The Signalling Situation on the P.RR.**

The situation on the P.RR. left about everything to be desired. The Signal Engineer had originally been appointed through a letter to the General Superintendents from the General Manager reading in part, " You may consult him as you see fit. His appointment will not detract from your authority in any way," or words to that effect. His job was to design the signal standards and print the signal requisitions and by use of a copying press make impressions in a record book, signing them and sending them to the Engineer for Maintenance of Way for signature, from whom they passed to the Purchasing Agent. He had one man to help him. He had been sick for a long time, had no authority, and his persuasive qualities had almost lapsed. He gave me requisitions to write, which I declined to do. I could still go back to the Lackawanna if I wished to. I asked for more help and the Engineer for Maintenance of Way told me I could build up an organisation. I started the next day, in each case suggesting a man and urging my chief to ask for him, and in every instance, after that engineer had talked with me, he gave permission for my chief to appoint. The latter and his only predecessor had been in England and Scotland years before, studying the signalling there, which was entirely mechanical, and the Union Switch & Signal Company, the first American company to make interlocking signals, was manned in the actual manufacturing departments by Englishmen.

In the eleven years I had been away, the P.RR. had greatly expanded and had changed many of its practices. At interlockings the top arm governed the main through route, the other arms, as many as four, governing to diverging routes. Sometimes the lowest arm of all was provided with a route indicator to show other routes, especially into yards. The automatic signals were largely electro-pneumatic, two arm, two position, home and distant. Track circuits were largely of the neutral polarised type similar to those on the Lackawanna, but were satisfactory largely because of the use of good stone ballast, or at least freedom from carbon dust near the rails. Cut sections were few and block section lengths 4,000-ft. to a mile long. The P.RR. organisation covered New York to Philadelphia and Washington to Harrisburg and Pittsburg, with many important branch lines. The Lines West organisation covered Pittsburg to Chicago, Pittsburg to St. Louis, and also many important branch lines. Many of these lines were leased. The Lines West had appointed a Signal Engineer, with considerable authority, W. M. Grafton, and he embodied in his standards a lot of his own ideas and some which my chief, Mr. Fowle, had but could not get adopted on our own lines. His automatic signals were one arm, three position lower quadrant, motor driven. Vertical for clear, midway for caution, with white, green and red light respectively, horizontal for stop. The P.RR. used this middle lower quadrant position for the "permissive" signal in manual block which permitted freights to follow freights without stopping, and a passenger train to follow a freight after it had had time to make the next siding—which it generally did—plus ten minutes. On both the P.RR. and on the Lines West a train stopped by an automatic signal could proceed after waiting one minute. Later it was allowed to do so immediately after stopping. The Lines West interlocking signals had two arms only, the top one for straight through, the bottom arm reading to all diverging routes. There were additional local rules on all divisions, and as some of the shunting and other engines ran over as many as four and perhaps five of them, there was a good deal of confusion. The General Superintendents were practically supreme on their Grand Divisions, usually made up of three or more ordinary Superintendents' Divisions, and our job was to persuade them to do things our way. The Signal Engineer made plans for mechanical interlockings, showed cranks, compensators, lines of rodding and location of rodding carriers or wire pulleys, the distant signals being wire pulled as well as most of the dwarfs. He also made the locking diagrams and dog sheets. All circuit plans, however, were made by the signal contractor furnishing the frames. On the big divisions, largely four track, two adjacent tracks were run east or north bound, the other two west or south bound, the passenger lines being on the outside. In several places there were double track branches. The main tracks were numbered 1, 2, 3, and 4. In some cases the second arm governed, for example, from 1 to 2 or from 4 to 3. In others it governed to the main track of the branch. It only took a few months to get the practice established of the second arm governing in the same direction of traffic as the top arm—governing crossover movements in main line—and the third arm to the branch. This was comparatively easy to accomplish, as in several cases main line trains had been diverted to branches in error, resulting in serious delays.

Late in the autumn of 1903 our General Manager persuaded our President that another officers' trip abroad was in order. A general Superintendent of the Lines West, Bob McCarthy, Andy

Kaiser, Superintendent of Telegraph, P.RR., and the Assistant Signal Engineer were selected to go. We left early in January, 1904, and were back by the end of February, visiting London, Crewe, Liverpool, Edinburgh, Glasgow, Berlin, Dresden, Paris and Antwerp and seeing many interesting things. Early in the January the General Managers of the P.RR. and the Lines West had appointed their Signal Engineers to get together, iron out the differences in their signal systems and report. I attended two or three of their meetings before I left for the foreign trip. They made a pretty good attempt at arriving at a uniform system and their report was referred to the transportation officers' associations of both the lines. The eastern one turned down anything that savoured of the west and the western anything that was east, so that everything was deadlocked.

The P.RR. used gravity batteries for operating its track relays, signal hold-clears and controls. The Lines West used storage batteries charged from gravities and, not believing two sources of power were needed at power interlockings, employed the all-electric system while the P.RR. used the electro-pneumatic. Both used lock bars mounted outside the rail. As the lines improved their roadbed and increased the width of their rail heads, several cases occurred, (with more or less disastrous results), of bars being forced up and out beyond the wheel treads, permitting points to be thrown under trains, usually under rear cars, the operator having thought the train had passed clear. This led to the requirement that track circuits should lock the point levers as well as control the signal operations and to the consequent rapid development of this system of control. Charles C. Anthony, later my assistant, had done the first work along these lines when Superintendent of Signals at Altoona from 1900 to 1902, and he and I did a lot to amplify the system. When a train passed a clear signal the route was locked electrically as well as mechanically. When the signal lever was restored to normal the route continued to be locked electrically, but the locking on each pair of points was released as the train left its track circuit, providing the greatest flexibility for changing routes quickly. The releases were made in reverse order for trains moving in the opposite direction if the signals were cleared.

The first semi-automatic terminal signals were installed at Jersey City on the P.RR. as early as 1891. The inner home signals for entering the station tracks had home and distant arms.

Each track could hold two trains. If the end section of track was obstructed the distant arm could not be cleared owing to the track circuit being occupied, and if both sections were occupied then the home arm was held at stop. The first through route locking referred to above was made effective in a large terminal on the Lackawanna line at Hoboken from typical plans we furnished in December, 1907, and at Philadelphia on the P.RR. in January, 1908. We had a race to be first and they beat us in the actual installation.

The great new station at Washington was under construction soon after, combining all lines entering the city. F. P. Patenall of the Baltimore and Ohio and I were the signal committee. As I remember it these two roads owned the terminal and a number of southern roads were tenants. Anyway, the Presidents of the two roads alternated as Presidents of the terminal yearly. Both roads used the white light for clear, so we " compromised " on green for that indication, decided to use through route locking and semi-automatic signals. The main " tower " had a mezzanine floor to take the vertical spring combination six or eight feet high but when our circuit men finished their work the actual spring combination was less than three feet wide, if I remember rightly. Meanwhile the unification of the signalling on the P.RR. and Lines West was at a standstill. I had made a number of inspection trips with our various general officers and bit by bit we found out the weak spots. As a result of my experience on the other roads I was constantly recommending " surprise tests " (a bad expression, later changed to " efficiency tests ") of the enginemen's observance of signals, but I failed to get far in this direction as our people felt it might be regarded as " snooping " on the men's work. However, in the middle of March, 1905, I was sent south with our General Superintendent of Transportation, Charles M. Sheaffer and our General Superintendent of Telegraph, Dan Stewart, to study the operation of single track automatic disc signals on what is still called the Queen & Crescent Line, in other words the Cincinnati, New Orleans & Texas Pacific Railroad, whose President had been General Manager of our neighbour the Philadelphia & Reading. (The C.N.O. & T.P. RR. had formerly a most unenviable record and was once popularly credited with having three collisions a day. This was, of course, a great exaggeration but it is known that in one month of the year 1889 there were 30 collisions. It included the old Cincinnati

Southern line, originally built by that city itself, a single track 336 miles long, from that place to Chattanooga, abounding in curves and tunnels. By the year 1905, however, it had been track circuited and automatically signalled throughout this distance and become one of the best worked lines in the United States). After two days of unusual kindness on his part and that of his Superintendent Waite and Signal Engineer W. A. D. Short, he called us all in, gave us unlimited facilities for travelling and turned us loose. " Let them go out and talk to the men, that's what they want " he said. "Anything we could give them could be done by correspondence," an attitude not generally taken but a very sound one. I had had a talk with him and as we left he said "Ask them what they think of ' surprise tests '." We did. Several enginemen said " We didn't like it at first, but we know where the dead line is and if any cuss running against us doesn't stop he may smash us up, so we don't want him on the road." That settled it with us and with their backing our report was so strong that our tests were started in earnest ! In a few weeks one of the mountain divisions that was pure as the unbeaten snow and which had reported a perfect performance said they could not operate up the hills if they had to stop at stop signals, so they were told to shorten their trains until they could. Out of this grew tests on forty or fifty performances of all trainmen, signalmen, etc., and it was all accepted without a kick from anybody worth listening to.

**Standardisation of Signalling Principles.**

In May, 1905, the big opportunity came. I went to New York to attend the meeting of the Railway Signal Association. The General Manager telephoned that he wanted me to go west with him from Philadelphia that evening. With him on his car was Dan Stewart, who had made inspections with me only a week or two before over some of our northern branch lines to Buffalo. After we were settled in the evening I opened up on some of the things we had seen. There was no continuity of signals. Distant " switch signals "—protecting isolated pairs of points—were the same as distant block signals. We would thus receive a clear distant " switch signal " and 4,000 to 5,000 ft. ahead of it a stop block signal ! When the General Manager accused me of being an alarmist, Dan Stewart spoke up and to my great surprise said, " Mr. Atterbury, he hasn't told you half of it." Of course, I was a special pleader and he unprejudiced and a man to be trusted. The next two days and nights we were engaged on an inspection trip over the Lines West. Eventually I had to listen to Mr. Atterbury and Mr. G. L. Peck, General Manager, Lines West, talk for about two hours about the inability of the line officers to get together on their Signal Engineers' report of late 1903 ; that both sides were prejudiced ; that they thought signals were too expensive and their own practice always better than that of any other roads, etc. Finally my chief said, " I will put up Rudd, who has worked on the New York Central, New Haven, and Lackawanna, knows how to do work cheaply and has no false ideas of our perfection." And Mr. Peck said, " I will put up Frank Rhea, who worked in our Signal Engineer's office, is now a Divisional Track Engineer, who has ideas and is not at all prejudiced about the beauty of our system." He wired for Rhea and on May 25, 1905, a date of some consequence in American signalling history, we four had another two hours conference on the train. We were given the assignment to travel over the different railroads and consult with their signal and other engineering forces and operating people. We were then to " sponge the slate," formulate an ideal system of signalling, recommend such changes as we considered warranted to attain this ideal as far as practicable, and harmonize the signalling practice of the entire Pennsylvania system of lines. I attended the usual one day meeting of the Association of Transportation Officials (A.T.O) and then went to Pittsburg to meet Rhea. We started on a series of trips which lasted until the middle of August, our report being dated August 18. We travelled over 10,000 miles on the P.RR. and Lines West and on sixteen other roads, visited the five signal manufacturers and some glass works and had five meetings with the New York Central Lines committee engaged on similar work. My General Manager told me to get enough copies printed for all operating officials, enginemen and trainmen. I asked him to read it first. He did, taking until four o'clock the next morning, and then had me get confidential copies serially numbered, providing enough for all the members of the A.T.O. referred to above, plus a dozen extra. He cursed me for keeping him awake he was so interested ! I was to caution each man that he would be held personally responsible for keeping the document strictly confidential. The committees on interlocking and block signals of the two associations were instructed to analyse it and report.

## The Rudd-Rhea Report.

Some of our radical recommendations were: All high signals to have illuminated arms as ideal, but for the present to be semaphores, upper right hand quadrant. (The position light signal later realised this ideal). Horizontal for stop, with red light; 45 deg. up for caution, with yellow light; vertically up for clear, with green light. (We were then using lower quadrant and white for clear). The number of arms on high interlocking signals to be three, with three lights. (The P.RR. was using from one to five and the Lines West two). Automatic block signals to have one arm and two lights. (The P.RR. used two arms and lights, the Lines West one). All signals to be made automatic or semi-automatic, even outside automatic signal limits (block and interlocking), in order that all such signals should give their most unfavourable indication directly a train passed. All the arm signals to be equipped with a second so called "marker" light giving its most unfavourable indication, in case the active light should become extinguished. Speed signalling, to be adopted, with high, limited high and low speeds shown by the three arms at the interlockings in place of signalling the routes as hitherto. Special distant switch and home switch indicators instead of semaphores, until their use was made unnecessary by installation of track circuit controlled signals throughout. We also recommended a few special signals, and a change in train classification (head signal) and rear and marker (tail) lights and we certainly started something. This report was never released to any other railroad, except that one copy was sent to the New York Central Committee, until 30 years later, and then only in part as ancient history. It took fourteen years after I first advocated green for clear and yellow for caution on the Pennsylvania System to get it, and when I asked permission to release the report twenty-five years later and was asked how much of it was obsolete, I had to reply that nearly all of it had been adopted on that system, although some of it had not.

The Railway Signal Association at its 1905 meeting in New York recommended the upper right-hand quadrant signal for all new work. It had already recommended the green light for clear.

In 1906 after a two days meeting of the P.RR. A.T.O. and much other discussion a number of revisions were made by us and by the committees and eventually the recommendations of the associations were made to their General Managers. It was a glorious fight while it lasted and we saw our chief recommendations adopted in principle. The three position upper quadrant signal had been patented by the then Signal Engineer of the Baltimore and Ohio, the patent being purchased by one of the signal contractors, to whom we had to pay royalties until the manufacturers finally got together. The P.RR. used the new standard on all new work and renewals. The Lines West were reluctant to make any changes, " on account of added expense," and made little if any alteration for some time. After the controversy was settled on paper the principal parts of the report (except green for clear and upper quadrant signals, already settled) were presented to the interlocking and block signals committee of the Railway Signal Association by the P.RR. representative and there ensued a war which I think lasted nearly seven years. The committee met time and again and a whole week's meeting at Detroit, Michigan, was one of the high spots. The West—that is railways west of Chicago—had largely single track lines and many of their men advocated a one arm signal for entering interlockings. This would stand at clear (vertical) for straight through, the arm being 45 deg. up for all other routes and to the next signal in advance on any route. Point indicator lights to indicate the routes and only one light to be shown on the high signals. T. S. Stevens of the Santa Fe, one of the finest Englishmen I ever knew—and I have known many—led their fight and his line eventually adopted this plan. The P.RR. System, New York Central System and Baltimore and Ohio, which needed much more, were accused of trying to dominate the West. The committee, of which I was chairman during the whole controversy, consisted of twenty-five men who fought all day and fraternised at night and some of the dearest friendships ever formed were those made in that committee. The meeting in Detroit was an example of this. We were (except for personal expenses) the guests of the Michigan Central, one of the subsidiaries of the New York Central lines. Our motto, introduced by H. M. Waite or Ed. Wendt, was read each morning. It ran " In essentials unity, in non-essentials liberty and in all things charity," then a chapter from a book which was a travesty on our President Theodore Roosevelt's policy, after which we went at it hammer and tongs. Azel Ames, Signal Engineer of the Lake Shore line, a subsidiary of the New York Central, raised the burning question, " Where should a signal govern, how fast and how far ?" And that was a big question ! We worked usually from 8.30 a.m. to 5.30 p.m., then went on a Michigan Central tug for some fresh air up and down the river, took dinner at some shore resort, and returned to fight again till perhaps midnight.

If Rhea and I had recommended upper left-hand quadrant signals instead of right-hand we would have done a better job. The New Haven, on the advice of C. H. Morrison, adopted them and uses them now on at least one division. We did recommend that signal masts should be located next to the track governed, or on bridges over the right-hand inter-track space. If the arm had pointed over the track the cost of moving out communication wires and the danger of arms fouling in them would have been decreased, while in many cases visibility would have been increased with foliage back ground, as noted before. We recommended that arms should be painted to contrast with the background, but this was not accepted, as obviously the background might change colour several times a year. The Pennsylvania System adopted a yellow arm with black stripe, with a pointed arm and two lights, one on each side of the mast, for all signals, usually automatic block, indicating " stop and proceed " as the most restrictive aspect. All other stop signals had a square ended arm with two vertical lights. The first upper quadrant three-position signals, which were electro-pneumatic automatics, were installed for trial on the P.RR. on the suburban branch from Philadelphia to Elwyn, about 15 miles, and put into service on September 25, 1906. I lived on this branch and our General Manager told those who were doubtful of the safety of the step that I would be the first one to suffer ! The adoption of the recommendations required a constant fight with the inertia of the operating people. As an example of this I may mention that the General Manager wanted to impose absolute block for opposing trains and for passenger trains following or being followed, instead of operating by time table and train orders only. I was permitted to attend some of his staff meetings. At one of them he said,

" Gentlemen, I have been trying to put the block system in effect on this railroad for three or four years now, and about all I have got is reasons why it cannot be done. Now, I am going to do something I seldom do. I am going to issue an order. A week " (or ten days or maybe two weeks, but which is not remembered now) " from this noon I want every foot of this railroad where passenger trains run to be under the block system. We will recess for half an hour. There are telephones outside. Get busy." The quotation may not be word for word correct, but it is pretty nearly so, and he got his block system.

Some of the block stations were equipped with hand lanterns and flags for a while, but it worked. Then he appointed a committee to see how it was working out and what additional facilities were needed. On one division it was found that "meets" were made between block stations on train orders to both trains, one ordered to take the siding. The Superintendent was told he must hold one train at a block station until the opposing train had cleared and reported clear. He said he could not do it and make his schedules and was told he had better try, or some one else would be given a chance to try. He issued his orders and was surprised that his trains made better time because the drivers ran with confidence and speed. But it took the General Manager to break the inertia. He was one of those men who gave you a job to do and—you did it or else! And I had no bed of roses. The Signal Engineer's health was failing fast. The children of Frank Thompson, a former president of the P.RR. and whom I had known when I was on the road from 1886 to 1892, had in the spring of 1907 provided two scholarships of $600.00 a year to be awarded annually to the sons of P.RR. officers and men, who could qualify in the college of their choice. August 1, 1907, was a great day for me. Mr. Fowle, the Signal Engineer was made Consulting Signal Engineer, I was made Signal Engineer, C. C. Anthony, whom I have mentioned, was made my assistant and I learned that my son, William, who was within a month of eighteen, had passed his examinations to enter the Sheffield Scientific School, Yale University (my Alma Mater) and had won one of the scholarships. This was the turning point in my career. Things began to move, in spite of inertia and opposition of a part of the Lines West and the seven years war in the Signal Association. We got results and it began to look as if the signal system of the United States and Canada would eventually become uniform. Then another radical change took place and again the P.RR. was in the forefront. Frank Rhea had left the railway and gone with the General Electric Co, and then into the public service, leaving me as the surviving member of the team. In 1908 I was elected President of the Railway Signal Association.

## The Development of Light Signals.

Light signals for outdoor use, both day and night, began to come into use together with a.c. track circuits, necessitated by the electrification of steam lines. The first colour lights in America without spectacles, shutters or moving parts, except the relays, were used in the East Boston tunnel of the Boston Elevated in the winter of 1904-5. The first colour lights for daylight use were seen on the Brooklyn Bridge, New York City, in 1908, and the first on the P.RR. were installed in connection with the Hudson River tunnels and the terminal in New York in 1910. The first three position upper-quadrant signals giving three block indications on the P.RR. were seen at Jersey City, in August, 1911, and its first a.c. motor signals with induction holding device and mechanisms operating directly on the signals at the top of masts between Bowie and Landover, near Washington, on October 1, 1912. An a.c. power line fed the signals and track circuits through step-down transformers, but in the case of power line failure there was no reserve power and signals were " out " until the line was repaired. The generators were placed in pumping stations which supplied the track water troughs. The P.RR. had electrified one line from Camden, New Jersey to Atlantic City, and also used the d.c. third rail system from Newark, New Jersey, to the New York terminal, but after several years of discussion this scheme was felt to be unsuitable for fast through passenger and heavy freight services and it was decided that a high tension a.c. power line should be installed feeding at 11,000 volts to overhead contact wires and that the signal power line, at 3,500 volts, should be pitched in in creosoted trunking laid on top of the underground duct line which would carry the telegraph and telephone cables. The work was started on a small stretch of the main line from Philadelphia to Paoli, a distance of about 20 miles, which was also a heavy suburban line. The four track contact wire supports were massive—later they were changed—and the mile or two first erected formed a tunnel covering over the track which prevented signals mounted on these supports from being seen at any great distance and, of course, a flicker was produced every two hundred feet or so. This was trying to the enginemen's eyes and it became necessary to lower the signals in some way so they could be seen under or on the supporting bridges. In 1887-8 Professor Hershell Koyle of Swarthmore College, near Philadelphia, made a signal arm equipped with parabolic reflectors and a lamp which turned with it, the light being reflected to show the arm both day and night. It was pretty good up to about 2,000 ft., after which it bunched up and looked like a full moon. Only two or three were installed on the P.RR. for demonstration purposes but the idea of constructing a position signal for both day and night, which would be as visible at dusk and dawn as at other times, remained in the minds of some of us for years.

Just at the time when we were developing the necessity for different signals for our electrification project, Dr. William Churchill, the colour light expert for the Corning Glass Works, read a paper before the New York City Railroad Club describing tests he had made with arc lights in lighthouses and the effects observed when electric headlights on locomotives caused phantom lights in signals. The next morning he and I had decided that, on account of the very recent development of the Madza lamp with a concentrated filament, it should be economical to erect rows of lights to give four positions of an arm instead of three, as with the ordinary semaphore. The only moving parts would be the relays to light the various rows of lamps as required and these relays could be housed securely from the weather. He agreed to look after the optical features of the scheme and I was to build one or two signals, if the P.RR. would let me, as the arrangement seemed ideal for the electrification area. Our people agreed and in 1914 we developed the idea. The first signals were wooden boxes and installed at Paoli. Adjustment of the lamps had to be very close. I remember during the early autumn, when the nights were getting cool and humid, the signals were hardly distinguishable in the early morning but were brilliant after about 9 or 10 a.m. We had shimmed up some of the lamps with blotting paper. This absorbed moisture and swelled, throwing the small filaments out of focus. As it dried out in the morning they went back into place. The first signals with metal frames were put in service on February 14, 1915, and were constantly being improved. The line ran east and west and in the early spring all the rows of lamps on some of the signals would appear to light up at sunrise. They had been all right when erected but the sun was northing and the lamps reflected the sunlight for perhaps an hour or two and for a period of perhaps two weeks. Then other signals would become affected and the trouble spread like smallpox, turning my hair grey, but it was eventually corrected by various means. These signals were later made standard for new work and renewals on the whole P.RR. System and are so to-day.

The last tabulations I made were January 1, 1935, exclusive of the Long Island and Pennsylvania-Reading Seashore lines, when 11,511, or $71\frac{1}{2}$ per cent. of 16,102 P.RR. signals were position lights. On January 1, 1936, 5,063, or 82.3 per cent. of 6,150 miles of automatic block signals were position lights. Only two or three other roads adopted them however, as the colour light was growing in favour. Some roads use position light dwarf signals and colour light high signals and one, the Baltimore and Ohio, a combination colour and position, employing two vertical greens, two horizontal reds, two upper right-hand quadrant yellow and two lower right-hand quadrant lunar white, with white lights above the one unit for high speed, below for medium speed and no white light for low speed, a very fine system.

Several years after position light signals had begun to be perfected, the Japanese, who were always snooping around to see what ideas they could borrow or steal, purchased 15 or 20 signals. They did not get the improved ones but had to have those—then obsolete—exactly like the original "tombstones" which their agents had seen on the P.RR. I have often wondered why the British Isles went to colour lights instead of position lights, as the latter eliminate all troubles due to change of hue in fogs.

When America entered the war of 1914, Mr. Atterbury, by that time a Vice-President of the P.RR. left to become General in charge of the Transportation of the American Expeditionary Forces. The Government took over the railroads. My job was, however, practically unchanged. After it was over and "the General" returned there were rumours of a consolidation of the P.RR. and its Lines West This was duly effected and in

March, 1920, I was made Chief Signal Engineer of all the Pennsylvania lines, reporting to the Chief Engineer of the system. The Signal Engineer of the Lines West became my assistant, but after two or three years he retired and one of my Eastern Lines assistants, W. M. Post, like myself a native of Connecticut, took his place.

**Modern Developments.**

Since 1906—perhaps before—the Interstate Commerce Commission had been seeking authority to order the railroads to install block systems where it thought it necessary, but without success. After the war a law was passed giving the Commission this authority and also covering automatic stops and speed control and almost at once the block signal part seemed to be forgotten and the automatic stop or control became the focal point. In 1923 the Commission ordered approximately 50 railroads to install these devices. The first automatic stop seen in America was invented by Axel Vogt and Joseph Wood of the P.RR. and installed near Altoona in 1880. A glass tube was attached to the engine near the ground and if broken by hitting a trip it opened the air brake pipe. Being struck by too many loose obstacles, it was placed on top of the cab in 1881 and engaged with an arm extending over the track and operated in connection with the semaphore arm at stop. In 1901 the Boston Elevated installed a trip stop alongside the track which operated an angle cock on the cars and other subways did likewise. My line in its New York passenger terminal had installed a modified device in the North and East river tunnels fitted with three finger ends and designed to operate with valves on cars which were protected from operating if hit by obstructions along the tracks. Several other devices had been installed for experimental use and one in particular seemed to be favoured by some members of the Commission and its engineers. The officers of the P.RR., relying on the intelligence, discipline and generally fine performance of their locomotive staff, had opposed taking control of a train from such skilled men feeling they could, if informed of conditions ahead, do a better job of train control than a device which acted as a certain signal engineer said, "without differentiating mentality." If we had to spend a lot of money then we might as well spend some more and get something worth while.

The signal contractors with whom we did most of our business had been quietly working for several years to perfect a system of speed control, high, medium and low, corresponding to our wayside signal system, and had it about ready. For a week the motive power folks and ourselves spent our nights on the trains and alternate days in Philadelphia and Pittsburg, after which we put the proposition up to the I.C.C. and received their permission to try it out on a single track branch line where we would have safety from collisions on other tracks. This gave all the complications of multiple tracks operated both ways with little interfering traffic. Half the line was operated from a dispatcher's office at the suggestion of the Commission's engineer. On the other half the train set its own route ahead. When plans were being made I was asked if we wanted a cab signal. All the apparatus was there for operating and it would only cost about ten dollars an engine. I said that we might as well have "all the fixings," so the engines were equipped.

The story of this development to completion over obstacles of all kinds has been described in American periodicals and cannot be covered here. The first time I rode an engine I perceived that the by-product cab signal was the real answer. It gave the information of conditions ahead that General Atterbury wanted, without taking the control of the train away from the engineman and I take the credit for being the only one except two men, one on and the other working for the Commission, who realised what we had. It cost a lot of money and years of work, but the P.RR. has now practically no automatic stops and a large amount of cab signalling. The coded circuits of this device have led to greater refinements, developed so that the same track circuits will control wayside as well as cab signals. We now charge storage batteries, which in case of line circuit failures provide substitute a.c. power for track circuits during interruptions. Line circuits employing similar principles make practicable the centralised traffic control by which the signals and points on an entire division may be operated from one or two small machines in central stations, and the observation of signals by enginemen largely checked, with a minimum of line wires—a great feature just now when copper line wire is hard to get for non-war purposes. I know of them but not much about them, and anyway I have written enough for a man who retired over five years ago and is old enough to know better!

I find that I contributed a paper to the Proceedings of the Institution, which appeared in the issue for 1914, page 69, entitled "American Signal Practice compared with British." I have no copy of this and some parts of the present article may be a repetition of what I wrote them. In the journal *Railway Signaling* —then known as *Railway Signal Engineer*—for July, 1921, page 264, appeared a contribution by me entitled " The Development of Position Light Signals," while a summary of the principal features of the Rudd-Rhea report will be found in the issue for August, 1935, at page 424. I desire to express my best thanks to the proprietors of that journal, the only publication in English exclusively devoted to railway signal engineering, for preparing the typescript of my present contribution to the Institution's Journal and thus greatly facilitating my task.