Railway Signaling and Interlocking

A Discussion of One Road's Practice and Some Remarks on Automatic Stops

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The following is an address delivered by Mr. Rudd before the Railway Club of Pittsburgh recently. It has a timely interest, in view of the discussion on automatic stops now going on in the columns of this journal. Mr. Rudd refers, in the course of his talk, to the article of his in The Signal Engineer for May, 1913, which summarized so ably the case against automatic train control. The following is printed by permission of the Railroad Club of Pittsburgh:

It is usual in an address of this kind to start with Adam and Eve, or at least with the flood, and work down through, explaining the evolution of signaling and the reasons for the changes, devoting about an hour and three-quarters to these preliminaries, leading gradually to the new system that we have, and then let the audience draw on its imagination for the answer, the time having expired. I have done it and lots of auditors have strayed away. To-night I want you to stay with me for a few minutes, so I am going to try the experiment of leaving out the primary and secondary and tertiary stages and come right down to the signals which we are now putting in on the Pennsylvania Railroad, and which they are putting on a great many railroads, with some variations. I shall speak of the indications and "aspects" (a word not coined, but discovered in the dictionary by Mr. George W. Snyder, of the P. R. R., which we consider indispensable nowadays). I am going to leave out the home and distant system that is in use on a great part of the mileage of the country to-day, treating it as if it were obsolete (although it will be many years before it is so), and just tell you of our method of giving information to the enginemen and the means taken to insure the accuracy of such information by the signalmen, and lastly give a brief summary of the automatic stop situation (the panacea for all our troubles) as I see it.

We have started a new system with certain fundamental principles, the first of which is that a signal imperfectly displayed or the absence of a signal at a place where a signal is usually shown, must be regarded as the most restrictive indication that can be given by that signal. We have tried to design the signal so that if it is imperfectly displayed it will show in itself that it is not properly displayed. I will explain that a little later.

The second principle is that a red light or arm horizontal indicates stop, unless qualified by a more favorable color or angle of arm. When this scheme was first proposed there was a great deal of opposition to it because it required an engineman to run past a red light in almost every case—in every case, in fact, where a signal indicated a clear block with one exception. It had been done for years with interlocking signals, but we had not done it with automatics, and it was thought probably a bad thing to extend the use of the red light to the automatic signals. I think results have proved that it is not much of a mistake. Remember, then, that a red light means stop, unless qualified by a more favorable color indication.

Third: A given aspect conveys the same information at all places, at all times and under all conditions, so that an engineman knowing the physical characteristics of his road and the location of his signals may always be sure that he is obtaining the same information with the same signal aspect.

Fourth: The signal must indicate where and when trains must stop and the action to be taken after stopping—whether or not it indicates the condition of the block and, if it does, whether the block is occupied or clear. It must indicate when to prepare to stop or slow down and how fast trains may run under the changeable conditions at interlockings. It must show in itself when it is properly displayed.

Fifth: This information is all that is needed as to conditions ahead to enable an engineman to run safely, confidently and expeditiously if he obeys the indications.

To give this information the signals are divided into four classes—stop, caution, proceed and permissive. The stop signals are all red. The proceed signals show a white light in combination with red or green. The caution signals show a green light in combination with a red. And the permissive signal shows two horizontal green lights in combination with the red. The permissive signal is probably needed more on the Pennsylvania than on any other road. The great majority of the roads of the country, under manual block, issue a card to enable the engineman to pass a stop signal to enter an occupied block. We give a signal for it. We do not permit a passenger train to enter an occupied block; we do not permit a freight to enter a block occupied by a passenger train; and this practice has been pretty well extended, so that as a general rule on some divisions preference freight is run under absolute block. We have felt it necessary to indicate to the enginemen of fast trains, which are not permitted to accept a permissive signal, a difference between that signal and an ordinary caution signal. It is a stop signal to them, and it must be different from the ordinary caution (distant) signal, which they can accept. A few roads which do use permissive operation, as we use it, allow passenger trains to enter the block with the freight under the permissive, and for that reason there is no need for them to make any difference in the signal.

Stop signals are divided into two classes, stop and proceed, and stop and stay. Stop and proceed signals are the ordinary automatics to be passed as per Rule 504, looking out for a train in the block, switch open, broken rail, etc. These are identified by the staggered lights, diagonal lights, with pointed arms. The pointed arm may not be necessary, but the New York Central has used it a long time. In order to get a system which would be uniform on the Pennsylvania and the New York Central and some of the other roads which operate with us jointly we adopted the pointed arm.

The stop and stay signals have vertical lights, either two or three, with square or round end arm, so that when an engineman comes to a signal with a pointed arm at stop he can stop and proceed; if he comes to another with a square or round end arm he knows he must stop until he receives further instructions.

Caution signals are divided into two classes. First, those indicating one block clear, the next signal stop; second, those indicating the position of the next signal, but also indicating that they give no information as to the occupancy of the block. In automatic blocks a clear signal indicates that the track is clear to the next home and the next home is clear. In manual block territory under permissive operation you might have a clear distant, but there might be a train between the distant and the home. So that we have added the fishtail arm with vertical green lights. Those signals are distant signals purely and never go to stop and never indicate the position of the block, and therefore they do not show a red light. The rule is that a signal imperfectly displayed or the absence of a signal must be regarded as the most restrictive indication that can be given by that signal. Now, if the active light goes out and this signal is a stop signal, the most restrictive indication is stop. There-

fore we display a red light with the active light out. With the distant signal the most restrictive indication is caution; therefore we show a green light if the active light is out, so that the signal in itself shows what its most restrictive indication is.

Permissive signals indicate positively to a man that the block is occupied. The clear signals indicate clear track, except the clear fishtail distant, which does not indicate anything about the track. Now clear signals may govern, and do govern, the speed at which trains may pass an interlocking. The top arm is the top speed, the bottom arm is the bottom speed, and the middle arm is the middle speed. In practice the top arm clear governs the authorized speed at that point, the bottom arm clear not to exceed 15 miles an hour, and the middle arm clear not to exceed 30 miles an hour. The old scheme of signaling routes has been abandoned, and we have come to what may be known as speed signals at interlocking, where conditions change on account of the changed position of switches. We do not attempt to signal speed out on the road, where the curvature is fixed and the grades and the stations, etc., are established. But where the conditions change at interlocking we signal the speed.

The indication "Proceed at slow speed" is given for movements not exceeding 15 miles an hour with traffic when next signal is clear. An aspect with the bottom arm at 45° is what we call the "know nothing" signal, or anything you please. Proceed with extra caution prepared to stop. It may govern to an occupied track, it may govern against traffic over a short crossover; at any rate, it indicates that you may pass the stop signal above it, which governs the through movement, but you must look out for yourself.

The dwarf signals govern the same way as low-speed signals—stop; proceed with caution, looking out for anything ahead; and proceed with traffic, your next signal is clear.

The fishtail signals do not indicate the condition of the block.

You will notice that they are all consistent, they all display a red light in combination with others, where they indicate block conditions, except the one with the green over white, and that bothers more people than anything else in the signal business. It is a poor aspect, it is inconsistent. But it is the best we can get. It is a pretty valuable signal on the P. R. R. The Lines West do not ues it; they claim they do not need to use it. A great many others do not. The Pennsylvania does and the New York Central does, and I believe the B. & O. does.

This system as it stands, I believe, will remain unchanged on the Pennsylvania Railroad for a considerable time. Experience has shown that it is all we need, except for some few changes which I hope they will let us make. We have adopted a purple light to show the siding derail open. Some years ago the General Manager issued instructions that switch lights on sidings and in yards should not be red, that they were liable to confuse the main line runners; and that left us when we came to study it only one color to use for derails, and that was purple. It is a short-range light, similar to red, and yet it cannot be mistaken for it. We still have the red for the dwarf signal light next to the main track, governing movements against traffic on the main track and to the main track from sidings and yards. I hope some time to see these changed to purple, removing all low red lights except on main line switches.

And I have another "hobby," and that is green for clear and yellow for caution. A good many railroads in the country have adopted it, and to my mind it has very decided advantages over the present practice. That is where we have a white light in our diagrams substitute green, and where we have a green light substitute yellow, making in that case the yard lights yellow and lunar white, and the main line switch lights red and green, so there will be no confusion to main line runners with any siding switch light.

Our Lines West and a good many of the western roads omit the middle arm and just have two arms, using the top arm as shown in these drawings, and the second at 45° for low speed and vertical for medium speed. I do not see how any road that still has a home and distant signal can adopt that, because the home and distant signals show red and green, and that would mean the same as proceed at low speed. The green light in the stop signal must be eliminated before any road can adopt the simplified two-light system all the way through. But that is ideal, to have two lights and never less than two. Then if an engineman comes to a one-light signal he knows it is improperly displayed. At present, with us, he knows that if he gets one light on a signal it is improperly displayed. All the automatics have two lights, all the distant signals and manual blocks have two lights, and at certain interlockings he has three, and the fact that there are three there is shown him by the display of two arms on the distant signal, so where he comes to a two-arm distant signal he knows the next signal is a three-light signal. It helps the engineman to determine whether he has a light out at the home, and when the system is well learned there will not be very many enginemen running by signals because there is a light out.

We also have slow and stop boards and track tank signs showing lunar white and green. Then we have the coon tail. The coon tail is a very valuable adjunct to a coon. It is a very valuable adjunct to us in spots. We issue instructions that a man should slow down and then we put a coon tail up to show him where he should slow down. It is quite a good deal of assistance in marking slow points along the road.

As to the means taken to insure the accuracy of the indications, we are installing all our new automatic work with alternating current track circuits, because we find that power and current from trolley road lines interferes with our direct current track circuits. There are precautionary measures that can be taken with D. C. cicuits, such as double relays and cutting circuits up, which have been tried with fair success. The real cure for the foreign current is the A. C. track circuit, and we are not only installing all new work that way, but changing over some of the old. This carries with it electric lights on the signal and A. C. motors.

The cost of installation is heavy. It runs for double track about $3,000 per block, 4,000 or 5,000 or 6,000 ft. long; for two tracks probably $8,000 a mile. I suppose some of the expense end of that will come out of the 5 per cent advance in rates!

Operating and maintenance costs are below anything we have had. The electro-pneumatic signal runs about $160 a year per block. That on a four-track road is $640 a mile. The D. C. motor runs about $90, and in some fortunate cases we have had $75 quoted, but we are from Missouri. The A. C. runs not over $60. That means a saving of $400 a mile over the old electro-pneumatic. While it is more expensive than the D. C. motor, when the difference in cost of installation is considered, we think it is safer.

People do not appreciate the money the railroads are spending on signals to-day. They see these foolish-looking arms flopping up and down, but they do not appreciate what it costs to operate them and what they mean. There are so many other things we ought to spend our money for that they seem to overlook the signals somewhat. On the single track in places we are using what we call the controlled manual block, where we have a stretch of single track in a double-track line, and the track is pretty hot and we have had to issue a great many orders, we put in this controlled manual with the track circuit, so that both the signalmen and the track circuit have to go wrong and the trains go wrong also before we can get them together, and we are moving the trains in such places without orders to the trains and saving a great deal of delay. The delay of holding freights for orders often knocks them out of their running time and holds them back an hour or two. With this scheme they can skin through without time table rights, but simply on signal, and a great deal of delay is saved. We are using it on a third track in some places, and we are contemplating putting it on the two inside tracks in our four-track line in a few places, so we can handle three tracks in one direction under signal during certain parts of the day, and in the other direction during other parts of the day.

Now everybody understands about interlocking. The Stand-

ard Code defines it as an arrangement of switches, lock and signal appliances so interconnected that their movements must succeed each other in a predetermined order. In ordinary language it means that the levers are so hitched up that you have got to set up the route properly before you can clear your signal, and after you clear it you cannot change the route until you put the signal back to stop again. That is all right as far as it goes. But after you put the signal back you can change the route with the ordinary interlocking. You can change a switch ahead of a train; you could move it under a train, except that at the switch they have a detector bar which rises outside of the rail and strikes the wheel and prevents the changing of the switch until the car has passed over it. The detector bar is not wide enough to sustain the pressure on it with power interlocking and sometimes fails under the train. So we installed electric switch locking, so that when the train is on the switch it could not be moved. The train shunted the circuit and locked up the lever. Then we extended it to take in the fouling points. Then we extended it to lock the switches ahead. So that even if the switchman put the signal normal the switch would be locked until after the train passed over.

That was all right if you ran in one direction. When we tried to run the train in the other direction we could lock them up, but the switch farthest ahead that we did not want to unlock was the first one to unlock, and those we wanted to unlock were the last to unlock. Mr. Anthony, assistant signal engineer, Pennsylvania Railroad, solved that problem. After we got the switches locked up we had a case where an engineman reported that he had a clear distant which changed to caution just in front of him. He stopped just short of the home signal and found the train crossing over in front of him. If he had been about six seconds sooner he would have gone into the side of that train. Then we arranged the locking so that when a train entered the circuit 3,000 or 4,000 feet from the distant signal it locked the levers so the signals could be put to stop, but the route could not be changed until he had passed the home signal. That was a long step in advance. To provide for a train shifting we put in a slow release, which took two or three minutes to change the route. If a man consumes three minutes between the distant and home he can stop even if the home is against him. As a substitute we used a time release, so arranged that after a signal was put normal it would take two minutes to change the route. That means that after the engine has passed it will take two minutes to let him into the siding. Recently we have developed a scheme so that we can use the time lock if the train is approaching, but release as soon as it has passed the home, so we get all the quick release of the approach locking and all the economy of the time locking.

Last year we spent approximately $3,700,000 for signal work. This year we have $4.200,000 appropriated. It is probable that we will get four or five big interlocking appropriations and then some appropriation for the electrification near Philadelphia. I presume we will have this year over $5,000,000 to spend on signals. That makes you wonder where it all comes from. In talking with an attorney of a western road a while ago he said he had been before the postal authorities and proved to them that they were losing money carrying their mails; he had been before the Interstate Commerce Commission to plead for higher freight rates, because they were losing money on freight. He had shown the state commissioner of Illinois that they were losing money on the passenger business even at the present rate, and they could not cut down to two cents a mile; and he had shown the express company people that they were hauling their stuff at a loss. "And yet," he said, "you fellows are declaring dividends, and if those fellows get together where am I going to be?"

On our Manhattan Terminal, which is the best signaled piece of railroad in the world, we have automatic signals through the tunnels in both directions, and we have automatic stops The signals are so arranged that by throwing a lever in the big cabin at the terminal and another at the Hackensack drawbridge, five miles away, we reverse the traffic. If trains have been running west and have passed out of the block we lower all the automatic stops and put them out of business for westbound trains, and throw in service the automatic stops and signals for eastbound trains. We operate two or three trains that way daily in order to be sure that everything is working properly, because if we have one of our tubes blocked we will need it like the Texan needs his revolver—"damn bad." We are going to be ready for emergencies. That is the only place where we use the automatic stop. Bulletin 63 of the Union Switch and Signal Co., most of whose works they have built out of the profits they have made off the P. R. R., states that the first automatic stop was invented by Mr. A. S. Vogt, of the P. R. R., which consisted of an arm sticking out from the signal and a glass tube on top of the cab, which when stuck by the arm was broken, thus opening the train pipe. I think that was in 1889. I remember it well. I went in the signal business in 1888. In 1889 Mr. Vogt's glass tube was put on an engine on the Pittsburgh Division. They did not arm themselves with any substitutes, and when they came through the Gallitzin tunnel an icicle hit the thing and the emergency went on, to the edification of all concerned. I think that was the last time it was used on the P. R. R.

There have been some 2,000 automatic stops invented and over 1,000 patented. The one we are using is the Hill automatic stop. That is comprised of three parts, like all Gaul. The first part was invented by Mr. Kinsman, as near as I can get at it, and the Union Switch and Signal Co. arranged for its use. I may not be right. I do not want a libel summons, but that is what I have heard. This is hearsay evidence. They have adapted it to the electro-pneumatic cylinder, which Mr. Kinsman did not invent. And we decided to put it in our tubes under the Hudson River. That was one of the funniest things that ever happened on the P. R. R. There are very few people that know about it. There will be more after this.

The Committee of Three, not the Arbitration Committee or the Three Wise Men, but the Committee of Three on Signals of the New York Terminal, of which I was a member, decided that we would use the automatic stop in the tunnels. We decided that we would not put them outside, because the interference with snow and ice might be very troublesome. The principal object was to prevent the angle cock on the train, which, when hit, opens the train line, from being interfered with by lumps of coal and crossing planks and things of that kind lying along the road. So we decided to install it in the tubes only. The committee made their recommendations to the Committee on Yards and Terminals. I think Mr. O'Donnel was a member of that committee. And they approved it. Then it was put up to the big committee, the Joint Committee on the Operation of the Yards and Stations and Structures. They approved it. With all that tremendous influence back of it, it is no wonder that the vice-president and the president approved it. We equipped all our electric locomotives and all our multiple unit power and sent a trial train out on the Long Island. The first trip it struck a piece of crossing plank and got stopped, and then we made the discovery that even if we had only put the trips in the tunnels the trains that ran outside might hit things. We did not get at it by synthesis or analysis, but by hard knocks. Then Mr. Hill started to see if he could develop something, and he did, which device is shown in the Union Switch and Signal Co.'s bulletin No. 63.

It is a mighty ingenious proposition and is working with very satisfactory results on our trains to-day. So, when some people tell us there is no satisfactory automatic stop, we have to say that if you want that kind of thing we have just the kind of thing you want. I don't believe we want it for a good many years. It will tie up your railroad where you have mixed traffic. The conditions on the Interborough and in our tubes to-day are ideal for an arrangement of that kind. Trains are run at approximately the same speed and the same spacing in the rush hours, and the same class of trains and equipment, high-class passenger trains, no slow drags or shifting movements, and the

simple fact that it works out there is no proof that it will work out on the steam line.

[NOTE.—In connection with the subject of automatic stops I would like to call your attention to an "Analysis of Causes of All Noted Steam Railroad Accidents" from July 1, 1908, to January 31, 1913, based on reports of the Interstate Commerce Commission, by Mr. P. J. Simmen, of the Northey-Simmen Signal Company, given on page 114 of the April, 1913, issue of *The Signal Engineer*, and my reply thereto on page 164 of the May, 1913, issue of the same publication, which might be of interest to the members of this Club.]

I honestly believe that after we have got our roads signaled with what money we have left after we have paid the income tax and the other taxes, and the excessive amounts which we are compelled to pay by legislation; after we have got rid of all the grade crossings in New Jersey at our own expense and done a few other little things that need fixing, and have tried out discipline and our safety committees have done their work and after the enginemen have become awakened to the honor of their profession, and the fact that good men are being imperiled when the careless and slovenly men are protected and backed up, after the men get so that they feel that they should weed out the poor men—and there are a few—with the improved discipline, improved feeling, 99 out of 100 of the accidents and collisions, which might be prevented by automatic stops, would be eliminated and we would not have the dangers which the automatic stop imposes of taking control of the engine out of the engineer's hands. I do not believe that any engineman running wants the control of his machine taken from him at a critical moment. I do not think it is necessary. After we have done all of those things if our safety first movement will not take care of the balance then I think the time will come to try, not automatic stops which apply the emergency, but a speed control that will take care of the speed as soon as it reaches a given limit. I don't think we want the emergency stop. I don't think we want to take the control of the engine from the engineman if he is attending to business. I think we should have some device that will control it for him and register it. Men are working on it and it will not be invented by a man that does not understand the business.

It is a crime the way the U. S. Patent Office is issuing patents to poor devils that can't afford to pay for them, that are not worth the paper they are written on. I had a patent offered to me five years ago, invented by a Baptist minister in Tennessee, assisted by a grocer, bearing the indorsement of the U. S. Government, for an improvement in the art of controlling trains. It consisted of a trigger stuck out alongside the track, which hit an angle cock on the engine, but it did not open the train line. Instead it opened the outlet of a cylinder on each side of the engine, containing ten gallons each of black oil, the cylinders being located just in front of the drivers. As the oil was poured on the rails the drivers slipped round so that the train could not proceed any farther. That is true. Those fellows sent that to me and I could have bought it for only $10,000; but our people would not do it! You can see how the poor inventor is appressed. They finally got a committee and it cost this country $50,000 to investigate just that kind of stuff.

A fellow came into our office the other day and Mr. Anthony listened to him for two hours, and the fellow was in earnest. I never saw a more earnest man, even at a revival meeting. It was an open circuit, of course, but wires will not break in such cases, we are told. When the train struck the point of the trip it closed the circuit, if Providence was kind, and it put the current through a flashlight powder, which exploded, making a flash of light. In order that the engineman might not think it a flash of lightning he had it liberate smoke, which filled the cab, and then the engineman knew he ought to stop or choke to death. If he still disregarded the fire and smoke and proceeded to go ahead into the mouth of hell, he had two cartridges with bullets in them and these cartridges exploded and the bullets were aimed to go into the train line without injuring the engineer or fireman.

Those are just samples of what we get every day. Then you will see articles in the daily press about how the railroads through meanness and parsimony will not adopt immediately the first automatic stop that is handed out. It is a hard situation. Maybe some paper will print some of this and perhaps change the course of public opinion. The Manufacturers' Association are doing a great deal in that line. I can not help but feel that a great Club of this kind can do a great deal in disabusing the minds of the public of the idea that if they get an automatic stop the millennium has come. I am much obliged to you for listening to me so long.

DISCUSSION.

R. L. O'Donnel, General Superintendent, Pennsylvania Railroad. "It occurred to me while Mr. Rudd was speaking that his scheme, as outlined, is a finished product, but the enginemen using the signals must recognize that we are passing through a transition period of signal construction. Many times the upper and lower quadrant signals will be found within a few miles of each other, and this calls for close attention on the part of the engineer. Referring to the figures given by Mr. Rudd (millions of dollars being spent yearly), it will be readily understood that it is impossible for the railroads to come to the finished product immediately, so that enginemen who are interested must bear with the railroads in trying to reach that finished ideal of Mr. Rudd, though the work is going on constantly.

"Mr. Rudd took occasion to take a 'fall out' of Mr. O'Donnel, and I cannot help referring briefly to the Manhattan Terminal Operating Committee which considered the plans of tracks, crossovers and signals. During a discussion one day on the question of signals at this terminal, Mr. Rudd found that all of the tracks were wrong which the superintendents and engineers had planned for the movement of trains, in that they did not conform to his idea respecting the placing of the signals. Mr. Rudd was working under the assumption that the tracks should be built for the operation of signals rather than for the movement of trains. After he had found fault with the manner in which the tracks were laid out, and had shown how it was impossible for him to signal these tracks, someone asked him whether he really wanted to operate the trains or build signals. After considering the matter for a short time he said, 'Well, I think we will be able to build the signals after the tracks are completed,' and he has built what he claims, and what I believe everyone will acknowledge, is one of the most magnificent systems of signals in the United States."

A. B. Pollock, Supervisor of Signals. "One question I would like to ask in connection with the aspect showing a distant signal to an interlocked home signal outside automatic signal territory. This signal, in addition to performing the function of a distant signal, would also be a distant switch signal for a switch located between the home and distant signal. Would it not be better practice to have a separate signal to indicate the position of the switch?"

Mr. Rudd. "The theory is that the switch light is the home signal; that the distant signal to be used for the home signal is the one that tells nothing about the occupancy of the track. It does not make much difference to a man whether the signal indicates stop at a switch light or a semaphore. He has the information that he has got to stop and his job is to come under control prepared to stop at the red light wherever it is.

"I presume Mr. Pollock refers to the condition where we have a distant signal 3,000 or 4,000 ft. from the home and perhaps 2,000 ft. in which we have a switch. In that case the man must be prepared to stop at that switch, and if he finds it all right he must still be prepared to stop at the home. Of course, that loses time. It may have some element of danger if that engineman 999 times out of 1,000 finds the switch right and the home against him and gradually relaxes his vigilance and runs faster than he should after receiving the caution signal, and so gets into the open switch. I would say that in a case of that kind it might be properly covered by an automatic signal. It is our troubles that lead us to improvement more than the

misfortunes we escape, and the difference between a man and a jackass is that a jackass never changes his mind. So perhaps we may decide that our present practice is wrong and that we may need an automatic signal at that point, so arranged that if there were anything on the track or the switch open, the signal would show stop, and if the track were clear and the next signal at stop it would show caution. We tried that in one case where we had two or three switches strung out one or two thousand feet apart. Of course, a train might come up against a red signal without any distant, but a fast train under absolute block would never do this except for signal failure or switch open, and in the latter case it probably would not get by very far, while under normal conditions it would receive caution and clear. I originally advocated another aspect for distant switch signal something like a canoe paddle with a hole in the middle. Our people did not take kindly to it, and when I got out over the country and found the objection to a multiplicity of aspects we pulled in our horns on it. I have had the system criticised because there were too many aspects. I analyzed the number of signal aspects on the leading railroad in this country a short time ago and found that there were 165 that enginemen had to remember. You can see how many there are here. Another one probably would not hurt very much."

Guy P. Thurber. "I cannot let the opportunity go by without thanking Mr. Rudd for the chance to see what an engineer has to learn. I am not a locomotive engineer. Probably most of you will recognize me as having delivered a lecture once before you. But if I were an engineer and were put up against a line of signals like that and had to learn them, I am afraid I would make a mistake some time and go by. I was at one of our safety rallies here a few weeks ago. About 6,000 members could not get into the original hall. And the main thing that seemed to be in the minds of all the speakers was the danger to the human element. They were trying to educate the poor engineer and fireman not to stay up too late and not to go into the saloon and all these things. Now, what is going to take care of that sort of thing? I judge from the remarks of Mr. Rudd that he evidently has not been on a train that has been stopped automatically. If he had he would not have said there would be danger in stopping the train. I have been on trains going at 60, 70 and 75 miles an hour that were stopped automatically, and on freights running 30, 35 and 40 miles, and the conductor talking with me said, 'That is the finest stop I ever saw in my life. No engineer could make a stop like it.' Government engineers were sitting in the train and one of them turned to the engineer and said, 'How did it go?' The engineer said, 'I could not beat it.' That is an automatic stop.

"I would like very much if Mr. Rudd and all the signal engineers here would listen to a paper I will deliver before the Pittsburgh Branch of the American Institute of Electrical Engineers on the 10th of June. It will be a technical paper on exactly what has been accomplished by automatic control of trains, illustrated with 100 slides, which Mr. G. B. Gray's brains, an associate of Mr. Rudd, has been the means of bringing out. I think when engineers know what train control is, how it works and how simple it is, they will be glad to give it at least one of Mr. Rudd's trials before all the money appropriated by his company is spent."

Mr. Rudd. "I would like to correct Mr. Thurber in his quotation of some of my remarks. I did not say anything about it being dangerous to stop a train running 75 or 80 miles. I have been on trains with the automatic stop. I have examined several. I have ridden on the engine. I know what they will do. I said a slow drag freight running nine or ten miles an hour would stop with unpleasant consequences, or with words to that effect, when the emergency application was applied. Mr. Thurber is, of course, interested in the automatic train stop and speaks possibly a little selfishly. I spoke in the most altruistic frame of mind. Speaking selfishly as a signal engineer and with disregard for all the other branches of the service, an automatic train stop would be a mighty good thing for me personally. I figure it out this way. We eliminate the human equation of the engineer that we hear so much about.

"Now when you take the control of the engine out of the engineman's hands you remove a great amount of his responsibility. But in removing the human responsibility, the human equation, from the engineer, you place it on the signal maintainer, who has to take care of that stop and keep it in perfect order, along with a good many other things. As we all know the salary increases as the responsibility increases, not necessarily the knowledge, but the responsibility, and the result in all equity would be that the signal maintainer would receive the salary now received by the locomotive engineer, and he would receive the salary now received by the maintainer of signals. In that case the supervisor of signals would have to get more money and the inspectors more, and then out of pure shame the management would raise my salary."

J. K. Sherman. "I would ask as to the source of electric power for the signals where alternating current is used."

Mr. Rudd. "The Pennsylvania is equipped on the main line where we are now installing the A. C. signals with track tanks 20 to 30 miles apart, requiring pumping stations and steam heating plants for use during the winter; at these points generators produce current at 3,300 volts. We run an underground power line, No. 4 or No. 6 insulated wires laid in trunking about 20 in. below the bottom of the rail and the wires pitched in. The current is transmitted from the power plant through this line to transformers at each signal location and transformed to 110 volts for the motor and to 12 volts for the electric light and to track transformers with voltage varying from five to 15.

"At each signal location in addition to the transformers there are oil switches, so that if we get a short circuit or a broken line between any two signals, we can by these oil switches cut out the defective points, and by starting the generator at the opposite end of the section, keep all our signals going except possibly one or two. The current is fed ordinarily in only one direction. But at each power plant there is a duplicate generator, so that if we have trouble at one end of the line we can start up the generators at the other end of the line and keep a fairly continuous service. Of course, if we get our power line in bad trouble in two or three places, the signals in between are cut out; with the motor signal and primary battery at each signal, if there is trouble only one signal goes. With a storage battery the same is true. With our old electro-pneumatics we had a storm and the charging line (500 volts) for the storage battery, went down and was down for a week, and we kept the signals runnning from the storage. I think probably there is less chance of a general interruption from the D. C. with primary battery at each signal location than there is with the A. C. with the source of power 15 or 20 miles away. But the A. C. we believe must be used to guard against the dangers of false clear failures due to foreign currents, so that we are installing it as fast as possible, and as we have money available. And if you have your track circuit A. C. you might just as well make your signal motors A. C.

"We also get a good deal better light with the electric light than we do with kerosene. It is steady, and more reliable. Do not think for a moment that we have not been working on the light proposition. I have made a test in the last two or three weeks of some new lenses, inverted lenses, which do not weaken the direct ray down the track but increase the divergence 30 per cent, so that if the light is set at the center of the curve you get principal focus at the center of the curve and you get also light approaching the center and receding from it, so you get a much wider illumination than with the present lens. And we have been experimenting with some green roundels that have a 30 per cent more penetrative effect than the present ones. The light question is not a dead one yet by any means. Light is of course the essence of the signal at night and there cannot be too much study and effort devoted to its improvement."