Automatic Block Signaling.*

By Edward C. Carter, Chief Engineer, Chicago & Northwestern Ry.

The present development of automatic signals in the United States has been the result of years of experiment and trial, through which at last success has been achieved. The earliest application of this class of apparatus which was in any degree successful was in 1871, but no great advance was made until the years 1883-84 and 1885, when over 650 automatic signals were installed, and in the years 1886 to 1899 inclusive 5,834 were put in service. . . .

The semaphore taken abstractly is the type of signal which would undoubtedly commend itself to the large majority. This preference is based on the one feature of its greater visibility, and if this were the governing feature in the selection of an automatic signal it would unquestionably go a long way toward placing the semaphore first.

The primary and most essential requisite in an automatic signal is that it shall give the desired indications correctly, at the same time being subject to the least possibility of derangement, and that, always on the side of safety to the traffic to be protected. A secondary and imporant requirement is that an automatic signal shall be fairly economical in the consumption of the power required for its operation. Another requirement is that the original cost of installation and the subsequent cost of maintenance shall not be excessive.

Inasmuch as block signals are a means by which a runner receives information as to the condition of the line ahead without being obliged to stop to get such information, their value is dependent upon the clearness with which their indications are displayed. In comparing the semaphore and disc signals, there is practically no difference in the distance at which their indications can be seen for two-fifths of the time, that is, during the night. The same is true in time of fog or heavy storms day or night; it is again true on lines of heavy curvature day or night. Therefore, as block signals have their greatest value at night, in time of fog or storm, and on crooked lines, it would appear that the supposed advantages of the semaphore are more fancied than real. There is also no little force in the argument that so far as possible automatic signals should differ from those used in interlocking, and as the first cost of the enclosed disc is less and the consumption of power for operation is less than for the semaphore, there are many who prefer this type of signal. The objections to the enclosed disc are:

1. That the case can be covered by a damp, sticky snow and the signal obscured;
2. That the glass can be broken and the disc stem bent by a missile thrown at the signal;
3. That the face of the case may reflect the sunlight at such an angle as to render the signal indication indistinct during a portion of the time a runner is approaching it.

The disadvantages of the automatic semaphore are:

1. It may be frozen in the clear position by a wet snow falling and freezing on the blade and the connection between the blade and its support;
2. Its greater first cost and consumption of power for operation;
3. The greater liability of derangement of the semaphore as at present installed and the consequent necessity for a larger and higher skilled force of maintainers.

As regards the weight of these objections to the respective types of signal, that of snow covering the face of an enclosed signal case may lead to detention of traffic, but under the rule that an imperfectly displayed signal is to be regarded as a stop signal, it cannot lead to a dangerous condition. Regarding the second objection to this type of signal, it is an occurrence most unlikely to be experienced in such a way as to escape the notice of a runner, for the signal would have to stick at just the right point in order to avoid being improperly displayed. Regarding the third objection, there will always be a certain space through which the runner passes in approaching the signal in which the signal can be observed without its being obscured by reflection.

In the case of the semaphore:

1. Heavy counterweighting will reduce the chance of the signal being frozen in the clear position, but, better still, the use of a system of circuits in which the signal stands normally at stop and is cleared by the approaching train itself (providing the condition of the block is such that it should give a clear indication). With such a circuit the chances are that the signal would be frozen in the stop position and not in the clear, and would thus avoid the positively dangerous condition of giving a clear signal when the block might not be clear. If frozen in the stop position it would be neither better nor worse than the enclosed disc under similar conditions.

2. As regards the greater cost for installation and operation of the semaphore type, it is one that should not be considered if the company making the installation is convinced that the semaphore has decided advantages over the disc.

3. As regards the greater liability to derangement, this may in time be overcome by improvements in the apparatus.

* Extracts from a Report on the question of Automatic Block Signaling; being subject No. XXV. for discussion at the sixth session of the International Railway Congress.

A reference to the table given hereafter shows that opinion in the United States is about evenly divided on the question of the superiority of the enclosed disc against the exposed semaphore. The table also shows the extent to which automatic signal operation has developed.

Of the automatic block applications in the United States much the greater part are operated through a track circuit, about one-half being operated on the so-called "Normally danger" system. Where home block signals have no corersponding distant signal, the circuits for the home signal overlap the home signal of the next block so that a train is well within the protection of the signal of the second block before the home signal of the preceding block is allowed to clear.

The statistics regarding the operation of automatic signals indicate that no more reliable means of guiding trains has been devised. On the Chicago & Northwestern Railway, during a period of fifteen months, with 203 blocks, there were 4,062,340 signal operations due to trains. During this time there were 844 stops required by the signals due to all causes, or one stop to 4,813 signal operations. Of the 844 stops, 446 were due to broken wires, broken battery jars, and material which was defective; 62 were due to malicious interference with the system; 107 were due to neglect on the part of maintainers; 151 were due to accidental causes (lightning, maintenance of way men breaking bond wires, etc.) and 78 were due to causes unknown. Taking the case of all stops from all causes, it appears that for the 844 stops 20,000 trains were run through the 203 blocks (204 miles), or that of 24 trains each running 204 miles through 203 blocks, one is stopped once on its trip. Reduced to trains per day, this means that for an average of 44 trains there would be 1.8 stops per day. During the above period there were 8 reported cases of the signals having indicated cars on sidings that might foul the main track, broken rails and open switches. During the seven years these signals have been in use there has been only one false clear indication per 900,000 to 1,000,000 signal operations.

Automatic Signals in the United States 1883 to August 1, 1899, inclusive.

Year installed.	Clockwork home.	Enclosed disc.		Electro-pneu semaphore.		Electric semaphore.		Total.
		Home.	Distant.	Home.	Distant.	Home.	Distant.	
1883	12	......	......	......	......	......	......	12
1884	434	......	......	32	33	......	......	499
1885	151	......	......	......	......	......	......	151
1886	26	......	......	......	......	......	......	26
1887	122	17	3	......	......	......	......	142
1888	46	......	......	......	......	......	......	46
1889	20	......	......	23	22	......	......	65
1890	78	......	......	84	86	......	......	248
1891	31	70	......	63	65	......	......	229
1892	58	240	6	272	276	......	......	852
1893	61	195	5	244	214	......	......	719
1894	16	356	66	......	......	......	......	438
1895	......	122	36	......	......	......	......	158
1896	......	301	26	......	......	......	......	327
1897	......	436	350	219	218	12	6	1,241
1898	......	66	27	77	85	78	39	372
1899	......	334	318	135	115	62	7	971
Totals....	1,055	2,137	837	1,149	1,114	152	52	6,496

The American Railway Association has adopted the following definitions of terms to assist in the understanding of requirements and rules for operation of trains under automatic block signals, and as the definitions and requisites of installation represent the consensus of opinion of the best railway managers of the United States, they are given as showing what is considered safe practice. [These are already well known to our readers, therefore we do not reprint them.—Editor.]

The safe use of automatic block signals is dependent upon the maintenance of the highest state of discipline among the train operating force. This can only be attained by a rigid adherence to the rules under which the system is to be operated and the establishment of such efficient supervisory methods as will admit of the prompt detection of infractions of such rules. It is essential to the establishment of confidence in the reliability of the system that each case of a train being stopped should be reported promptly, to the end that the signal, if out of order, may be repaired in the shortest time, reducing the number of trains that would be unnecessarily stopped by it. Should a large number of stops be occasioned at certain signals by trains in the block ahead, a revision of the schedules may be desirable, or such a relocation or increase in the number of the block signals as will permit of an uninterrupted train movement. Such a complete record of all stops should be kept as will admit of a knowledge being had of each signal's performance and of the difficulties experienced in each case, together with the remedy applied. The tabulation and classification of these difficulties will give the most valuable information on which can be based the improvements which will lead to their elimination.

The rules under which the majority of the automatic signals in the United States are operated correspond so closely with those formulated by the American Railway Association that these latter rules are here given. [Not reprinted here.—Editor.]

Maintenance.

The organization of the Maintenance Department of Automatic Signals on the Chicago & Northwestern Railway may be taken as representing the general practice in this country. The signal engineer has a corps of maintainers, battery men and lamp men. A maintainer has charge of the inspection, maintenance and repairs of about forty blocks, the signals and apparatus being distributed over twenty miles of double track. His wages will average $75 per month. A battery man has charge of the maintenance and renewal of the batteries for about twenty, blocks together with other duties in the line of assisting the maintainer. His wages will average $45 per month. The lamp man has the care of filling, cleaning and lighting the signal lamps for about twenty blocks, and is required on occasion to assist the battery man. His wages average $30 per month.

A maintainer is required to ride over his entire district twice each day observing the operation of all of the signals. He is required to investigate, repair and report any case of irregularity in the operation of the signal system which comes under his observation or which is referred to him. He is required to so arrange his work that he shall have inspected carefully and in detail every part of the apparatus in his charge at least once every thirty days, making such tests of circuits, batteries and instruments as will enable him to detect and remedy conditions which if neglected would result in imperfect operation of the signals. He is held responsible for the care, operation and maintenance of all of the signal apparatus on the district to which he is assigned. In times of storm the entire force is required day or night to be on duty, going over the line and observing that the system is in proper working order.

The battery man is required to have in each battery house a certain per cent. of reserve cells, which he shall have set up and in proper working order, ready to be placed in circuit relieving the same number of worn-out cells. The maintenance of the gravity battery is essentially the same as other Daniell cells, except that instead of the addition of copper sulphate in small quantities from time to time as is the usual custom in renewing batteries on telegraph circuits, batteries for signal circuits have been found to give better results by making a complete renewal of the copper sulphate after emptying the jar and cleaning its elements. The battery man is responsible for the maintenance of the batteries at their normal strength and for their good electrical connection in their respective circuits, and also for the care and distribution of new battery material, old material being saved and returned to the storekeeper. The battery man is required to assist the maintainer so as to be familiar with all the circuits, instruments and methods of detecting troubles and remedying them. He is thus prepared for the duties of maintainer and is in line for promotion when an opening occurs.

The lamp man is required to clean, fill and light the lamps on his district. He has the care of and is responsible for the oil, etc., required, and for the efficiency of his lights; he is required to help the battery man with a view to learning battery work and being capable of assuming a battery man's duties when the opportunity offers. In general, the organization should be such that each man is fitted for the next higher position, and no man should be retained on the force who has not the capacity to acquire the knowledge required to permit of his being advanced.

The average cost of maintenance and operation of automatic block signals on the Chicago & Northwestern Railway for the year 1898 was $83.61 per signal, made up as follows:

Labor and material on signals	$32.33
" " on batteries	30.42
" " on lamps	20.86
	$83.61

Requisites of Installation.

The following points are given as a general guide in the installation of automatic block signals and as an amplification of some of the requisites laid down by the American Railway Association.

Efficiency in operation without extravagance in installation requires the most thorough knowledge of the present traffic requirements and traffic capacities of the line to be signalled.

The traffic requirements taken with the physical characteristics, including station locations and switches, will be the factors determining the lengths of the blocks and the consequent number of signals.

In the determination of the relative length of blocks, the principal factor will be the time required by trains in passing through them. The length determined by running time will be modified by curvature in the line and by the distances between stations and switch locations, the controlling signal being so placed as to give ample protection for switching and station operations. The shortest block should be of a length sufficient for the fastest trains being brought to a stop between the distant signal and its corresponding home signal, or where a distant signal is not used, between the home signal and the far end of the overlapping section controlling the home signal of the preceding block. The maximum length of block is limited only by the traffic requirements.

All signals should be placed either over or on the runner's side of the track, and the home signals so that they will assume the stop position after the head of the train has passed them. In early applications of automatic signals it was thought to be necessary for the runner to see the signal operate as the result of his train entering the block. The signal had therefore to be far enough within the block for the runner of the fastest train to be able to observe its movement before reaching it, and, as a consequence, on crooked lines and in time of heavy fog the runner of a slow train would find the signal at stop without having seen it assume that position. The result was that he either had to stop under the rules, or, believing that his train had operated the signal, go on with the possibility of finding the block occupied and causing the accident the signals were intended to prevent. This difficulty of correct interpretation of the signal indication is sufficient to condemn the practice of making such a location of a home signal.

Experience has demonstrated that a track circuit for controlling the signals is the best, and, though it has some disadvantages as compared with the wire circuit, still they are more than overbalanced by its affording protection in cases which the wire circuit cannot be made to cover without excessive complication in apparatus. All of the circuits and apparatus should be so arranged that the derangement of any part controlling a signal will cause it to assume and remain in the stop position.

In installation, each circuit should be carefully tested for conductivity and insulation. The resistance of track circuit should not exceed ½ ohm per ½ mile section, and its insulation resistance in dry weather should not be less than 20 ohms, or in wet weather not less than 4 ohms, per ½ mile section. In ordinary practice a 4-ohm relay is used in track circuit and current is supplied by 2 cells of multiple connected gravity battery, the elements of which are zinc and copper rendered active by a solution of sulphate of copper. The average internal resistance of such a cell is about 1 ohm. When the insulation between the rails is 20 ohms, with a combination of circuit and battery resistance, the discharge should be approximately 235 milliamperes, of which the track relay receives about 194 milliamperes. When the insulation between the rails is 4 ohms the total discharge approximates 356 milliamperes, of which the track relay receives about 173 milliamperes. The comparatively slight variations of effective current received by the track relay under the extreme conditions of track insulation above given, insures a fairly uniform pull on the armature of the electro-magnet, and permits of its more accurate adjustment and uniform operation.

All electrical instruments should be tested and proven to be of the proper resistance for their circuits and free from the possibility of crosses. Relays for track circuits should generally be located at the near end of the block and their battery at the far end, as an entering train will thus shunt the current so as to drop the armature of the relay and as the train proceeds, any increase in the amount of accidental foreign current reaching the rails behind the train will not be sufficient to energize the relay so as to close it. Battery for signals should be placed at the end of the line circuit controlling the signal furthest from the signal. This rule also holds for battery for indicators. In general, battery should be so placed with reference to the instrument it is to operate, that a cross between the wires forming the circuit or with foreign wires will not cause a false clear indication.

All line wires should properly be insulated and made up into a cable covered with lead, for, while the first cost may be somewhat greater, the security from crosses, and especially the protection it affords the instruments from the effects of lightning will, with its longer life, repay the increase in the original outlay. A well-proven form of lightning arrester should be placed in each circuit liable to be affected by that form of trouble. All relays should be provided with points so arranged as to give a rubbing contact.

The foregoing, taken with the requirements and rules of the American Railway Association, cover the more important features which should be observed in the installation, maintenance and operation of an automatic block signal system.

In conclusion, it may be said that for lines of heavy traffic, with high speed trains, an ideal system for controlling the movements would be:

"1. Interlocking plants at all points where there are switches in the main tracks, the home or advance signals being electrically slotted with a track circuit through the succeeding block. The towers to be supplied with indicators to give information regarding trains in the adjoining blocks:

"2. Automatic block signals placed as required to properly space trains moving between the interlocking plants."

Such a system will admit of the heaviest traffic movement, with the greatest safety, with the least detention, and at the least cost for protection.

As a result of seven years' experience in the use of automatic block signals on the Chicago & North-western Railway, and exceptional opportunities, as a member of the Safety Appliance Committee of the American Railway Association, for learning the experience of others in their use, the writer is convinced of their reliability and great value for the protection of life and property in railway operation, and has no hesitation in recommending their use when properly installed, maintained and operated.

The Goodwin Steel Car in Collision.

By John M. Goodwin.

I desire to propound a question or two in relation to the interesting articles recently published in your columns, concerning the comparative merits of steel and wood for freight car construction. In your issue of October 13, 1899, was a discussion on the subject of "Metal Draft Beams," with cuts showing a wrecked pressed steel car with malleable iron draft rigging and coupling uninjured. Now I am led to ask the

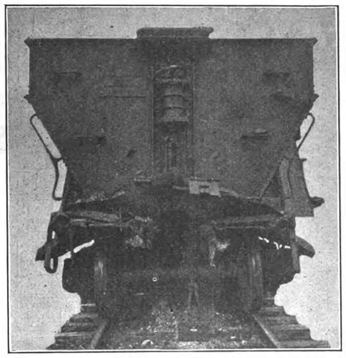

Fig. 1.

following question: After making a coupler and draft rigging as strong as is consistent with economy in ordinary railroad service and every-day accidents, does it not appear that it would be wise to construct the car to which this draft rigging is applied so that the car shall be stronger than the draft rigging, in order that, in case of a severe collision, the car may be saved from severe damage rather than the coupler?

I enclose photographs of a recent wreck of Goodwin cars built of structural steel and malleable iron. A train of 38 cars coasting down the mountains crashed into a heavy mountain mogul locomotive. The locomotive was backing up around a sharp curve running at about 18 miles an hour.

Photograph No. 1 shows the forward end of the first car that was in collision with the locomotive tender. No. 2 shows the damaged end of second car, and No. 3 is the third car with follower plates broken on forward draft rigging only. No. 4 shows rear end of first car and forward end of second car in elevation.

The metal buffer plates and the coupler on the forward end only of each of the three first colliding cars were demolished and torn completely from the draft gear castings. The rear couplers and buffer

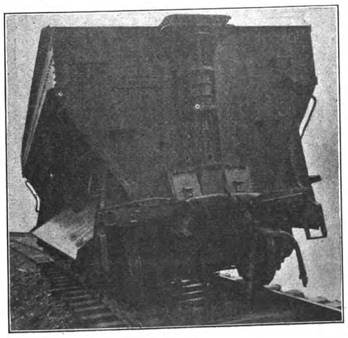

Fig. 2

plates remained intact and uninjured in each instance.

The sheet steel platform of the car that plunged into the tender was ripped from the malleable castings forming the end sill, the rivets being pulled through the sheet steel and remaining in the castings. The end sill castings were bent and twisted, but remained intact and unbroken. The running gear sustained no damage, and these three cars took the entire shock, remaining on their trucks and on the rails, with no further damage than here described.

There are but two sills under a Goodwin car; these two sills form a box girder and extend from end to end of the car. They are on the draft line and are the backbone of the structure; the aprons and the side girders very materially stiffen these two

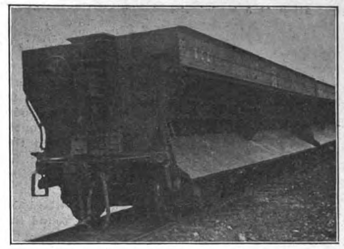

Fig. 3.

sills and tend to distribute the load or strain evenly, however applied, adding to their resistance in all strains brought upon the car either in ordinary service or in case of accidents. Further, these sills form a battering ram in case of collision, the efficiency of which is well demonstrated in the instance under consideration.

The colliding car tore off the coupler from the tender and the two sills crashed completely through the buffer plate and oak end sill of the tender. It required the combined services of two mountain moguls and a heavy hydraulic jack to wrench the car out of the tender, while the comparatively slight damage shown on this one end was all the damage sustained by the car in punishing the locomotive tender so severely.

There are many new features in the construction of the Goodwin car class "G" that I would like to discuss, but I will restrain myself and ask only a few more questions at this time.

Conditions of general traffic being equal, in car building, comparing steel with wood, does the lesser liability, in steel construction, to sustain damage from ordinary accidents, compensate for the increased cost of repairs in steel when damage is sustained? Does not the solution of this question depend materially upon the comparative structural strength of the steel frame with the wood frame? In any structure there is a certain amount of material absolutely necessary to resist a given blow with-

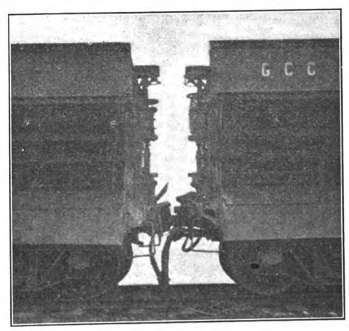

Fig. 4.

out changing the form of the structure. This required amount can be calculated, and when calculations have been made, is it not wise to resist the present tendency to "skimp" in weights, especially when added burden is given to be carried over the figured capacity? In the structure of the Goodwin car can be seen the results of special attention paid to giving sufficient weight and bracing to parts liable to meet with extraordinarily hard usage, and the advantages are evident in the use of malleable iron in small sections, which are easily removed and replaced when bent by accidents. The castings all being numbered and the rivet holes cored in them, require the minimum amount of shop work in repairing.

Thirty years of experimenting has resulted in the present standard, class "G," 80,000-pound capacity Goodwin freight handling car. This car is but little known at present by the railroad men of this country, for the reason that very few Goodwin cars of any one pattern have been built up to the present year. The object of the Goodwin Car Company being to perfect the car before putting out any large quantity. You have noted from time to time within the past few years in your paper, the slow but sure progress made in these cars, demonstrating the revolution in metal construction. The few defects of the