Locating Automatic Block Signals for Heavy Traffic*

First of Two Installments, Explaining Acceleration and Braking of Trains with Reference to Signal Stops

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BLOCK signaling had its inception years ago, when the semaphore signal was called into use at stations for the purpose of conveying to trains information as to their further procedure. It is even doubtful if these "train order" signals could be called block signals if the term "block signals" is used in its strict sense of "train spacing signals." However, it was not long before these same signals were used as real block signals when their operation for a train to proceed was made to depend upon the receipt of information from the next station that the preceding train had cleared the space between the two stations.

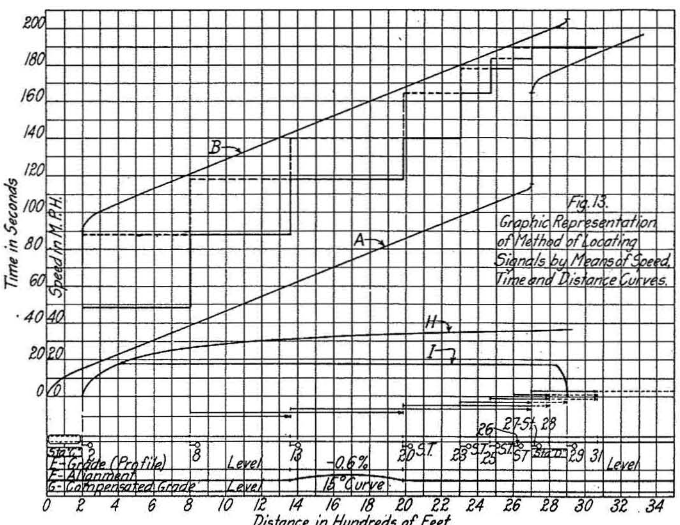

Fig. 13. Completed Working Diagram

If the towns were close together, the trains could be spaced close together and if far apart, the trains were necessarily spaced far apart, also. As these long blocks became prohibitive, block stations were located at intermediate points to permit more trains to use a given piece of track. Then as automatic block signals came into use they were located between the block stations and in many cases superseded the manual block signals and a still greater capacity for trains was thereby provided.

During this development, the signals at interlocking plants were used to indicate routes. These signals at first were in no sense block signals and were located solely with reference to the switches, crossings, etc., which they protected. In fact, the special track and operating conditions at interlocking plants are still the governing elements in the location of interlocking signals. But as block stations for the operation of manual block systems were frequently located at interlocking plants one set of signals was used for both the interlocking and block purposes. Later when automatic block signals came into use it was found desirable to have the interlocking signals serve also as automatic block signals, so that the block signals were located at more or less regular intervals between the interlocking signals, depending upon various physical conditions such as the location of stations, curves, tunnels, obstructions to the view of the engineman, and (not the least important) the location of signals on the other track. A great many block signals in use today were located in this manner and the fact that these signals are providing safe and expeditious movement of trains is clear indication that their locations are satisfactory, or at least, not very objectionable.

But an analysis of operating conditions and requirements soon discloses the fact that at least some of those practices in the location of block signals were economically unsound if track capacity was considered. Take for instance, the practice of locating signals for both directions opposite each other. The spacing of block signals depends in a very large measure upon the distance required for a train to stop after the application of the brakes—braking distance—the braking distance being less on an up-grade than it is on a down-grade. But if signals are located opposite (or on the same bridge) for both directions, the distance between signals will be the same on both tracks and on a grade, therefore, the block will either be too short for braking distance on the down-grade, or too long for maximum capacity on the up-grade.

There is a considerable saving in cost by locating the signals opposite, and where the traffic can be expeditiously handled by such an arrangement this opportunity to keep down the cost should be used. But where traffic is such that the track must be used to its maximum capacity, the saving in cost would be greatly overbalanced by the cost of delays to trains or even the necessity of running a few trains.

Location of Signal for Heavy Traffic

Similar arguments could be cited with respect to other methods of locating block signals. My analysis of the problem of locating signals for heavy traffic indicates that there are four main divisions into which all elements may be properly classified—namely—*Roadway, Car* and *Engine Equipment, Signal Equipment,* and *Train Operating Characteristics*—and I shall describe briefly the elements which in my opinion should be classified into each of these groups:

Roadway Elements

Curves in a track not only affect the view of signals but also the speed of trains—the speed affects the time a train will occupy a section of track and that in turn will affect the length of block, etc.

The profile also affects the speed of trains and there-

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by the length of blocks and location of block signals. Braking distances are determined very largely by the grades. Crossings, junctions, drawbridges, and other special arrangements affect the movement of trains. An open drawbridge or an occupied crossing are insurmountable obstacles and block signaling should be designed to provide for normal movements at such locations with only the restriction of train movement which normally prevails.

Stations, water tanks, water troughs, coaling stations and other similar physical conditions where stops or reduced speeds are necessary, must all be taken into account and the signaling should be designed on the basis of normal and maximum allowable speeds at such locations.

Car Equipment Elements

The motor characteristics are shown by the rate of acceleration from a stop, the normal and maximum attainable speeds for various grades for all the types of equipment to be operated.

The braking characteristic is fixed by the rate of deceleration and stopping distances under service and emergency brake applications on various grades for all types of equipment to be operated.

These two elements, motor and braking characteristics are of first importance and should be considered not only in their normal condition but under the most unfavorable conditions of wear, condition of track, weather, etc.

Signal Equipment Elements

Important points are the visibility of the signals, the time required to change from one aspect to another, the comprehensiveness and comparative simplicity of the scheme of aspects displayed by the signals, and the indications they convey. Also the system of signal control —overlap or single block—the use of automatic stops or train control, etc., must be considered. Schemes which may be used either to restrict or facilitate train movements under special or unusual physical or operating conditions, should be considered.

Train Operating Characteristics

This is the most difficult of the four groups to describe in definite terms. The other three all have either well known or easily determinable characteristics, but the personal equations of the enginemen or motormen or despatchers or towermen, or maintainers, are as variable as the weather. For instance, will the engineman or motorman start to reduce speed as soon as he sees the caution signal, or will he continue at the speed at which he is running until he reaches it and then reduce, or will he wait longer still and only reduce his speed when other conditions tell him it is necessary to do so? Some will do one thing and some the other and one man will not always do the same thing. If he is late he is liable to crowd ahead a bit and if he thinks he is close on the train ahead he is liable to hang back.

Solution Requires Broad Study

The signal engineer who is designing a block signal system for a line which is already in operation is fortunate in that he can by direct observation obtain fairly accurate data as to operating conditions, but where the line is not operating, or is operating under different conditions from those under which his signal system will function, he must fall back upon his experience and use his judgment as to what operating conditions will prevail, and set down his known quantities to cover the most unfavorable aspects of these operating conditions.

It has been found that by combining all the known quantities in proper relationship, a scientifically correct signal system may be laid out. This can best be done, graphically in the form of curves showing the characteristics of the various elements. The accompanying illustrations show a series of curves which represent some conditions in effect on the Brooklyn Rapid Transit System and which have been used in laying out the signal system on portions of that road.

While these curves and the data upon which they are based cover the equipment, roadway and operating characteristics of one railroad, they are being used merely as an illustration of the principals involved and any other set of conditions obtaining on any other railroad could be similarly treated. On a road with diverse traffic such as high speed passenger trains of few cars and low speed freight trains of many cars the method would obviously require that consideration be given to the operating characteristics of each type of equipment singly or in combination and the signaling would be laid out to provide for the most severe demands, in which event all other classes would be automatically covered therein.

Graphic Development

We propose to show the graphic development of the various elements which enter into the final "working diagram" on which the signal locations are actually plotted. First in the "working diagram" Fig. 13 it will be noted that across the bottom of the sheet is shown the physical characteristics of the railroad—track arrangement, location of stations, etc. If there are any bridges, interlocking plants or other factors having a bearing on the signaling they would also be appropriately shown and receive proper consideration.

The profile is shown by diagramatic lines, giving location, length and per cent of all grades and the alignment, also the location, length and radius of all curves.

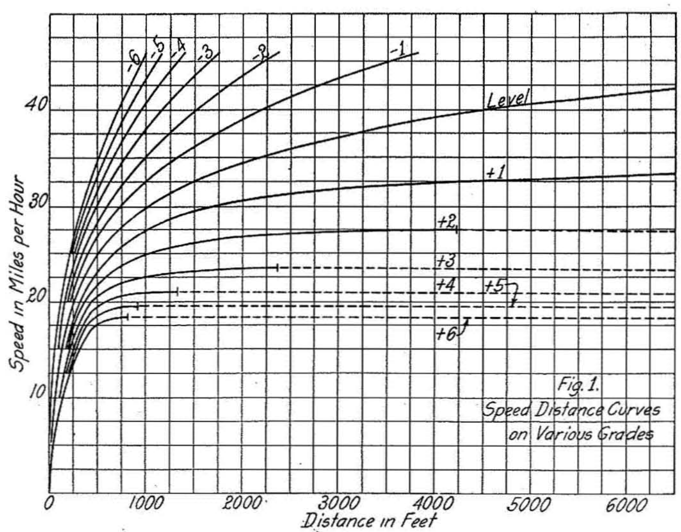
Above these diagrams of the roadway characteristics are the speed, time and distance curves, which are used in determining the location of block signals—curve A showing the rear end of one train and curve B showing the head end of the following train.

The given factor in the design of such a signal system is the minimum spacing of trains but it will be clear that other factors may be given and a maximum capacity or other results derived accordingly. These curves are the result of combining a number of elementary curves representing the roadway and equipment characteristics previously referred to, and in order to show how the whole process is developed, I shall describe briefly these individual curves:

To protect a train it is necessary to know just where the train is, whether it is moving or at rest and its location in relation to any train which may be following or which may be moving in the opposite direction. This paper is restricted in scope to the determination of signal locations for a dense traffic in one direction only.

Fig. 1 shows the speed distance *acceleration* curves for the 2000 series type all steel cars. These curves provide all the necessary information with respect to the ability of the motors to accelerate a car, empty or loaded, to the various speeds in m.p.h. indicated on the left of the curve sheet and the distance required in which to attain a given speed is shown at the bottom of the curve sheet. For example, if the car is free to move, that is, if the brakes are removed, and current is applied, a car at rest on level track will accelerate to a speed of 20 m.p.h. in a distance of 250 ft. Conversely, a car accelerating for a distance of 250 ft. on level track will reach a speed of 20 m.p.h. Similarly, it should be clear that a car accelerating from rest will, on up grades, require a relatively greater distance and on down grades a relatively lesser distance to attain the same speed or vice versa. It will be observed that a portion of the curves for acceleration on 2 per cent to 6 per cent grades is shown dotted—the dotted portions are all horizontal and show graphically that the limiting speed for the respective grades has been reached and no further acceleration is possible with this equipment no matter how long the train continues on that given grade.

The speed-distance emergency *braking curves* for the Brooklyn Rapid Transit System, 2000 series type all steel cars as given in Fig. 2 provide the necessary information with respect to the ability of the brake equipment to decelerate or stop a car, empty or loaded, moving at the various speeds indicated on the left of the curve sheet —the distance which must be provided in which to stop a car being set off along the bottom. For example, a car in motion on a level track with a speed of 35 m.p.h. will require a stopping distance of 350 ft. Conversely,



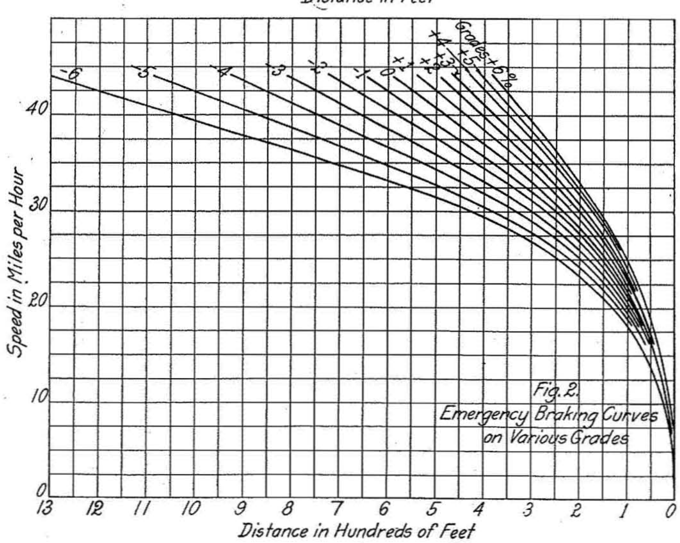
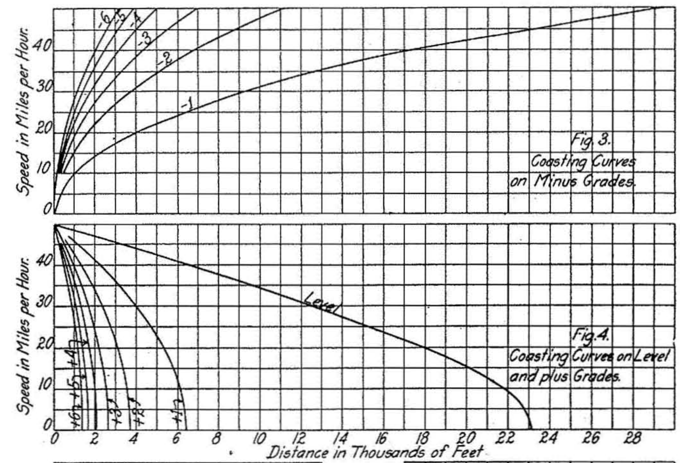


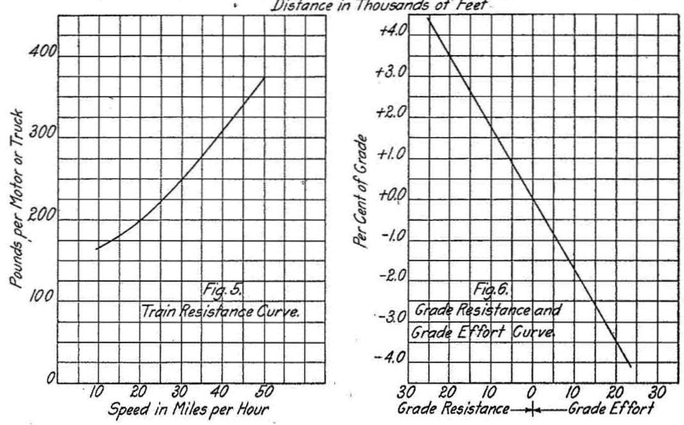
Fig. 1. Speed Distance Acceleration Curve
Fig. 2. Emergency Braking Curves.

given a distance of 350 ft. on level track in which to bring a train to rest we find that the initial speed of 35 m.p.h. must not be exceeded at the time of the emergency brake application if the train is to be brought to rest in the given distance.

Coasting is desirable, as it would hardly be economy to accelerate a train until it became necessary to begin braking for the stopping point. The curves for coasting are in two sections owing to the fact that on level track and on up grades the retarding forces result in a reduction in speed and the curves are shown commencing with an initial car speed of 50 m.p.h. The reverse is true for coasting on downgrades.

We have referred to different values for accelerating, braking and coasting with no changes in grade in the given or derived distances but the acceleration of a train will be according to the grade for the distance the grade continues and will be faster if the change is to a grade which introduces less retardation and vice versa; similarly with braking and coasting. The 2000 series of cars





Figs. 3 and 4. Coasting Curves.
Figs. 5 and 6. Train and Grade Resistance Curves.

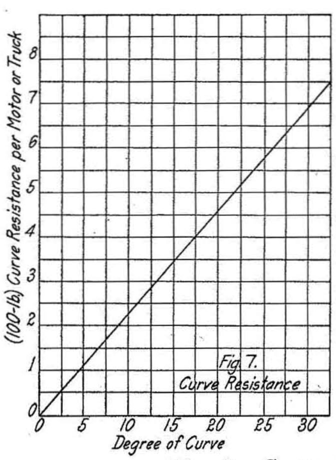
on the B. R. T. System are provided with means to make the rates of acceleration or deceleration constant whether the cars are empty or loaded. The essential factor from the standpoint of signaling, resulting from equipment so arranged is the ability to base the signal system on a constant value for deceleration.

The three essential curve sheets used in the design of a signal system on the basis of elements herein considered are shown in Fig. 5, 6, 7. The origin of the elements involved in these three curve sheets are explained as follows:

Train resistance shown in Fig. 5, comprises all of the forces which tend to retard the progress of a moving car on straight level track. *Track resistance* is due to the rolling friction of the car wheels on a more or less uneven rail surface. *Wind resistance* is due to the wind pressure on the head of the car and *the skin* friction on the sides thereof and *frictional resistance* due to the bearing of the motor, gears, journals, etc. The factor of train resistance is expressed in pounds per train, car or truck, according to whether the unit involved is a train, a car or a truck. The unit adopted herein is the truck because the two trucks of a car are similarly equipped with motors and brake equipment, the car and passenger weights are divided equally between trucks and when such is the case whatever values are derived for a truck will be applicable to a car or train.

Formulas have been developed as a means to determine the several elements of train resistance, including the different varieties of frictional resistance but are seldom used in practice owing to the great variations which obtain and which cannot be checked individually except by careful tests. Since these elements do not require separate consideration it is customary to determine the combined effect and the curve shown is the result of actual tests made by different authorities.

Grade resistance as shown on Fig. 6 is that additional element or factor which must be overcome by the car motors if the car is to move on an up-grade. If a given rate of acceleration is to be had increased tractive effort must be supplied by the car motors in addition to that necessary for the same rate of acceleration on level track. This factor, however, is considered as virtual increase in weight of truck and with the car motors developing the same tractive effort for the same speed the result is a lower rate of acceleration. For example, to raise 2000 lb. vertically would require a weight of something more than 2000 lb.—the amount in excess of 2000 lb. being required to move the weight while 2000 lb. would be required to sustain or balance the weight. Since a vertical lift is equivalent to 100 per cent grade it follows



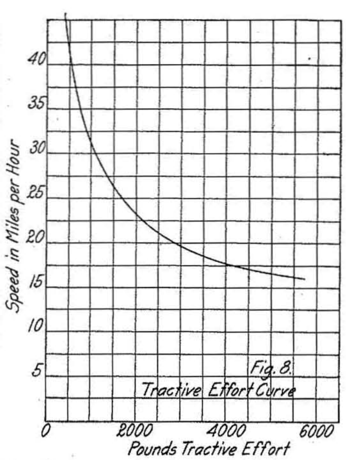


Fig. 7. Curve Resistance, and
Fig. 8. Tractive Effort Curve.

that to sustain or balance a weight or 2000 lb. on a 1 per cent grade it would require 1-100 of 200 lb. or 20 lb. per ton; on 2 per cent grade it would require 40 lb. per ton and so on. Therefore, 575 lb. would be required to overcome the effect of 1 per cent grade on one track of 28.75 tons (57,500 lb.)

By the amount that a 1 per cent grade imposes additional work on the car motors, so also by the same amount a 1 per cent grade acts to lessen the work required of the car motors in which case grade resistance becomes grade-effort and results in an increased rate of acceleration.

Curve resistance is caused by the movement of a train, car or truck along a curved track being retarded a certain amount due to the flanges of car wheels bearing on the rails. This resisting or impeding effect is proportional to the wheel base and degree of curvature and has been determined to be 0.8 lb. per ton per degree of curvature. It is expressed in pounds but instead of being used as an independent factor in computations it is generally reduced to terms of equivalent grade resistance and combined therewith.

Curve resistance is seldom a very sizable factor and only in exceptional cases and locations is it necessary that any consideration be given to it. Generally speaking this element may be neglected except on rapid transit lines peculiar to the larger metropolitan districts.

Tractive effort represents the ability of the car motor to perform the work necessary to overcome the impeding forces of train-resistance, grade resistance and curv-resistance and to accelerate the car. It is proportional to the current input to the motor and within certain limits the current input can be and is maintained at a value which will provide a uniform tractive effort. The specifications of the mechanical department require, and provision is made through automatic control devices located on the car to maintain the current input to the motors substantially at the value, commensurate with the speed, such that the tractive effort developed is constant between 0 and 16 m.p.h. thereby resulting in uniform acceleration. Above 16 m.p.h. the tractive effort is variable finally reducing to a figure which just counterbalances the impeding forces in effect on straight level track at the speed of 46 m.p.h. The curve shown is developed from curves furnished by the manufacturer of the car motors. Tractive effort is expressed in pounds per motor or truck.

(To be concluded in an early issue)

Sudden Ravings
(Tarnished Gems)

Under the spreading chestnut tree
The "Signal Smithy" stood;
The smith, a mighty hoss was he
Who did what e'er he could
But the foreman, oft, in fiendish glee,
Raisedell—as foremen should.

Measuring, beefing, hammering
Onward through life he went;
Each morning saw some job begun,
Each evening found him spent.
Something attempted, something done.
He ate and paid his rent.

Week in, week out, from morn 'till night
He put side sets in jaws
He didn't have to heat them much
To bend them with *his* paws.
He welded rods. He got them right,
With welds that had no flaws.

On Sunday, he would leave his bunk
To play a different game
And try to fit a lot of junk
Into a locking frame.
Some bars were long; some had shrunk
—and, today, they come the same.

When circuits first came into use
His soul was filled with fear,
He could not *see* the subtle juice
Which held the signal clear.
And pretty soon, he was a deuce
—a pinion out of gear.

No more he stands beside his fire
Fate folded up his mitts
His name is legend. With a lyre,
In Heaven, now, he sits:
Replaced, by six (in neat attire),
Who use screw-jaws, for fits.

W. H. F.