THE DESIGN OF A BLOCK SIGNAL SYSTEM BETWEEN GLOVER AND CHAMPAIGN ON THE CLEVELAND, CINCINNATI, CHICAGO AND ST. LOUIS RAILWAY

BY

LUCIUS ORVILLE CHAMBERLAIN

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

LUCIUS ORVILLE CHAMBERLAIN

ENTITLED THE DESIGN OF A BLOCK SIGNAL SYSTEM BETWEEN GLOVER AND CHAMPAIGN, ON THE CLEVELAND, CINCINNATI, CHICAGO AND ST. LOUIS RY.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

RAILWAY CIVIL ENGINEERING

[Signature]
Instructor in Charge

APPROVED:

[Signature]
HEAD OF DEPARTMENT OF RAILWAY ENGINEERING
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Preface
The Design of a Block Signal System between Bloom and Champaign on the Cleveland, Cincinnati, Chicago and St. Louis Railway.

Aim.

The aim of this thesis is to broaden my own field of knowledge, and to give to the students who may read these pages a concise idea of the subject matter in hand.

I aim to cover in the text the automatic block signal system designed in the following pages, and to show its connection with the interlocking plants at Bloom and Champaign.

Scope.

The scope of this thesis is to choose and to design, for a proposed installation, the best automatic block signal system.

To properly plan and design the safest and most economical system and to state the reasons for choosing that particular system in all its details, would take a much greater length of time than can be given to the subject.
Certain details, however, have been taken up with special emphasis. They are: Normal dangers versus normal clear, electric versus hose versus electro-pneumatic, the braking distance of a train, and the minimum distance between engines to handle the maximum traffic.

Acknowledgments:

In studying the field of signal engineering for the first time I have found difficult questions coming up, which I have tried to answer in a concise manner. In doing this I have received suggestions and material from the following men, and companies, and I have quoted freely from the books named below.

To Mr. F. S. Foote Jr. I owe my thanks for the electrical part of the thesis. Through many periods of consultation he gave me such instruction as was needed to get the control circuits in shape.

Mr. A. D. Cloud, Editor of The Signal Engineer, was very kind in offering valuable advice as to where I could find material to use.

The Hall Signal Company has been extremely courteous in sending pamphlets and in writing letters in regard to my work.

The books mentioned above are:


(6) Railway Signaling, written by a Staff of Expert Signal Engineers, published by The Electrical Journal, 422-4 South Avenue, Pittsburgh Pa., 1908.


(8) The Signal Engineer.

(9) Standard Handbook for Electrical Engineers.

I have attempted to give credit in the text for all quotations from these books. Some statements are near quotations. I take pleasure in acknowledging the use of printed matter and the advice of those who have so kindly assisted me in the work.
Conclusions.

The conclusions which I have reached are:—(1) That the normal danger indication should be used, (2) that the electric semaphore is the best and most popular form of signal, (3) and that the controls shunt will give adequate protection to opposing as well as to following trains.

Some minor conclusions, and comments, follow which are intended to indicate that the subject has not been treated to the fullest extent. In fact the author feels that there can be found here a good foundation upon which, to build a good and thorough discussion and design of the best block signal system to use on single track.

The closed track circuit, and the direct current operation deserve more discussion than is given to them here for I have not mentioned them elsewhere. The braking distance of a train, and the discussion of signal locations for the handling of maximum traffic is an important part of the subject matter and should not be overlooked. The overlaps and the control circuits are partially explained. The polarized relay
should be carefully studied for it may offer a safe and economic means of saving time wire. In the calculations I have uniformly used a velocity of forty miles an hour, which is not the correct thing to do. The velocity that should be used is indicated in the text. Slide rule calculations are accurate for this work.
Chapter One

Introduction
Introduction.

Axiom.

The track circuit is the foundation of every automatic block signal system.

Definition.

1. Block. A length of track of defined limits, the use of which, by trains, is controlled by block signals.

2. Block Signal. A fixed signal controlling the use of a block.

3. Home Block Signal. A fixed signal at the entrance of a block to control trains in entering and using said block.

4. Distant Block Signal. A fixed signal used in connection with a home (and advance) block signal to regulate the approach there to.

5. An automatic block signal system is one in which the signals are operated by electric, pneumatic, or other agency activated by a train, or by certain conditions affecting the use of a block.
(6) In signal work the primary circuit is the track circuit.

(7) Track Circuit.

An electric current flowing through the rails of a railway track.

(8) An open track circuit is one in which the two sides of the battery are not normally connected so as to form a circuit.

(9) A closed track circuit is one in which the two sides of the battery are normally connected so as to form a circuit.

(10) Alternating currents have been used in signal work. For the purpose of this paper the direct current will be used.

(11) A direct current is a current of electricity constant in direction.

(12) An alternating current is a current of electricity which flows alternately in opposite directions, its magnitude varying from maximum in one direction through zero to maximum in the opposite direction and back again according to the laws of simple harmonic motion.

Operated unit.

In interlocking this term is used when speaking collectively of switches, signals, movable frogs, derails and any other apparatus
worked or controlled by a lever in the machine. A signal may be an operated unit by unit power type of signal in meant that the power to operate one operated unit is at the location of the operated unit.

**Rules**

(1) In the event of any failure of the mechanism of a signal to work the signal shall automatically place itself in the stop position.

(2) A signal partially or improperly displayed must be regarded as a danger, or stop signal and be obeyed as such.

(3) The short circuiting or breaking of a track circuit shall cause the control circuits to be closed so that the control circuits may operate the signal mechanism.

(4) Automatic block signals are necessarily permissive as in case of a signal failure a train must pass the signal displayed in the stop position or else traffic would be delayed indefinitely. The rule is that a train may pass the stop signal, after having waited a specified time, and then proceed cautiously to the next signal.
Foreword.

Before a company would be justified in installing an automatic block signalsystem between two points they would need to have a traffic so large that by the use of block signals the company could handle trains more safely, and so much more economically as to pay a reasonable rate of interest on the investment.

The traffic on the Cleveland, Cincinnati, Chicago and St Louis Railway at the present time consists of four passenger trains and five freight trains, round trip per day. For the purpose of this thesis I have taken the traffic as sixteen passenger trains and twenty freight trains round trip per day.

The kind of an automatic block system to use is a question of economics that should be handled on a comparative cost basis. I have endeavored to give here the reasons for choosing the system that is named in the conclusion which is in the preface.
Normal Clean Versus Normal Danger

The object to be obtained by the use of automatic block signals on single tracks is to have a signal displayed in the stop position behind each train until the train has passed into the block beyond that which the signal governs, and to have a signal displayed in the stop position some distance ahead of the train governing movement in the direction opposite to that in which the train is moving. This object can be accomplished by means of a normal clean or a normal danger automatic block signal system.

Normal clean automatic block signals stand normally in the proceed position, and go to danger after a part of the train has passed them, remaining so as long as the train remains in the block which they govern.

Normal danger automatic block signals stand normally in the stop position, except when a train is approaching, and then they indicate proceed only in case the block is clear.
Figure 1

Figure 1 is a diagram showing simple circuits to illustrate the normal danger system. When a train passes home signal 1, going to the right in the sketch, the armature of relay 2 will drop, and complete the circuit through battery B, through the mechanism of home signal 2, to common, through armature 3 by line wire to armature 2.

Figure 2

Figure 2 is a diagram showing simple circuits to illustrate the normal clear system.
In discussing the relative merits of the two systems I have used numerous quotations. The following one from Scott indicates clearly that in 1908 the normal danger system had begun to gain ground, and that it would be only a matter of time until it would be widely used if not the standard system.

"The conditions that may set up a false or dangerous condition in a signal system are manifold; but their actual occurrence are few. The failures at danger can only wrongly delay a train; but failures at clear, by giving the engineer a proceed indication when such may not be safe, are the only ones that can really be termed dangerous. Such failures have in practice occurred on an average of 1 in 1,000,000 movements. On a normal clear system, an average 1 in about 600,000 has often been reported. Many such failures occur from inability of the moving system to move from its normal position. This not, principally, the external parts which are sensitive to such checks to movement as they are thrown by a powerful force, and with sufficient inertia to remove a retardation; but the light control parts,
whose motion is due to the expenditure of energy measured in thousandths of a watt.

"Among the causes of false clear conditions are, fusing of control contacts, improperly counterweighted banner or semaphore, breaking of the color spectacles, rusting of sliding parts, foreign currents, residual magnetism in relays, imperfect contacts, dust or insects in relay boxes, crossing or grounding of wires, interconnection of wires with common, poor armature pivot, failure of clutches or locks to return, breaking of mechanical connections, and poorly insulated circuit wires.

"The use of white as a clear indication is meeting with disfavor. This is due to the liability of a spectacle breaking, or the clipping off of its color film. The adoption of green or red for clear has many advantages, among which are the normal danger indication of a white light, except when a color spectacle is actually and properly before it, and the restricted conditions under which safety indications are given.

"Failures at danger may be caused by a broken rail, bowed wire rusted off.
broken, rusty channel jam, high current leakage between the tracks, broken wires in the relay, polarity reverses, track battery or signal circuits, exhausted track or main battery, poor connections, unsoldered joints, broken battery jar, useless or poor connection in switch boxes or controllers, burning of protective fuses, failure of an arrester, broken live wires, short-circuiting of an individual or a series of batteries, open circuit at motor commutator, failure of electric slot or locks, poor insulation, short circuit in relay and the depredations of mischievous persons.

"As far as visual indication is concerned, the normal danger position is undoubtedly the best, and has been so recognized since the inception of mechanically operated semaphore; while argumentative opinion from a purely electrically stand-point, also favors such a disposition. Formerly, standard normal clear circuits were more economical in initial installation, but this consideration no longer obtains."

Quotation from Ralph Scott. Automatic Block Signals page 10.
In speaking of the automatic block signal system Mr. Tratman says:—"In this system the train sets each signal at stop as it passes, it releases the signal behind, which then automatically returns to the proceed position." The normal clean system has been and is yet more generally used than the normal danger system. In the above quotation Mr. Tratman leaves the idea that the normal clean system was generally used. By statistics the condition obtains at the present time. The following sentence also bears out this idea, but it was written in 1901 seven years earlier.

Mr. Adams* says:—"The beginning of each block section is also indicated by a post. This post is about seven feet high and it bears at the top the words, 'Electric signal block,' the signal itself being set two hundred and ten feet in the block section, so that the engineman can see it move from the clear to the stop position." In the same book Mr. Adams points out that the normal danger system was being that of as the following quotation clearly shows.

"By an arrangement of electromagnets and wires presently to be described, the signals are arranged to stand normally in the stop position."

As early as 1876 Mr. Elliott approves the normal danger system. He says: "In the most approved systems the signal automatically returns to the danger position immediately upon a train entering the block, thus making it impossible for a second train to enter, ---- --."

In the Standard Handbook for Electrical Engineers, (13) 515, is found the following statement: "Another plan is known as the normal danger plan, that is, all signals stand at danger whether the block is occupied or not, and move to clear when the train has approached within a certain distance of the signal, moving to danger again when the train has passed. The latter system possesses several advantages if the road is operated by telegraph for part of the distance, but it is doubtful if a majority of these advantages do not disappear if the principle.

*W.H. Elliott, Signal Engineer C.M. & St. P. R.R. in Block and Interlocking Signals 1876.
of the absolute block system are strictly adhered to, in as much as the added complication means more weak points in the system."

The absolute block system is not strictly adhered to on single track work and almost every road has telegraph poles along its right of way. The above quotation, then, seems to favor the normal danger system.

The reason that a normally clear signal goes to danger is that the primary circuit being short-circuited causes the secondary circuit to be broken and the signal by the force of gravity assumes the stop position. If conditions should obtain such that water gets in the signal mechanism and freezes while there so that, although the circuits work, the signal will not move from its normal position, then the signal will give a false clear indication. Should the same conditions obtain on a normal danger system the signal would give a false danger indication which, as has been pointed out before, is not such a dangerous thing to happen.
The following quotation, taken from a letter to The Railroad Gazette from Mr. C.H. Platt in 1905, needs no comment.

"The normal danger is more efficient for reasons already stated and because high resistance magnetic coils are unnecessary. It lessens the dangers of lightning and residual magnetism, and decreases the liability of failure on account of chilled batteries.

While signals are installed principally for controlling trains in one direction, they give valuable information for other purposes if installed on the normal danger principle. Under the normal danger principle, a train may approach at any time with or without notice by changing the position of the signal; under the normal danger the signal clears only on the approach of a train and the clearing relay can be placed at any desired point, so that the engineer can see it clear if so desired, or at the entrance of the block, or in the case of short blocks, at the entrance of the next block in the rear. When installed in this way, trackmen and bridgemen working in sight of a signal are always informed as to the approach of a train, and
can govern their work accordingly to better advantage, and with greater safety to them selves.

"An double track engineers can be informed as to the approach or non approach of a train on the opposite track; can maintain higher speed past stations if no train is approaching, and avoid running between another train and a station if a train is approaching on the opposite track.

"Persons using highways or farm crossings in sight of a signal can be governed intelligently as to the use of the crossing."

"At commutation stations especially patrons learn to notice the position of signals, and if clear, indicating a train in the block, lessen their approach to the station, and are ready on the platform to take their train promptly upon its arrival, shortening the average stop to some extent."

"Automatic intermediate signals between interlocking points work in harmony with such signals if installed on the normal danger principle, with out change in locking circuits, or in operating regulations."
All Electric Versus Electric Pneumatic.

In this discussion I have merely listed the opinions of several writers upon the subject. Their opinions agree so well that I shall not raise an objection.

From Block and Interlocking signals by Mr. Elliott, page 221, there is taken this bit of history. "Invention having passed successively from the first pneumatic machine put in service in 1876, to a hydraulic machine used in 1880, to a combination of these or a hydro-pneumatic machine in 1884 and to the electro-pneumatic in 1891."

"Automatic signal may be operated by electricity alone or by a combination of compressed air and electricity. In the former case, each signal has motors or electric magnets operated from batteries which are charged by a line wire or are renewed at intervals. In the latter case, the valves of air cylinders attached to posts are operated by the electrical connections, the actual movement of the signal (and of the switch, in interlocking plants) being effected by the air, which is carried in a line of three inch or four inch pipe laid along the side of the road bed or buried between
the tracks. The pressure is usually 70 or 90 pounds.

"The ideal system for controlling trains on lines with heavy traffic and high speeds was suggested as follows by Mr. E.C. Carter, Chief Engineer of the Chicago and North Western Railway, in a report prepared for the International Railway Congress of 1903: (1) Interlocking plants at all points where there are switches on the main tracks, the home or advance signals being electrically dotted with the 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."

"The most successful system, and those generally alluded to when an automatic system is spoken of are those which depend upon electricity for the controlling agent, whether

* E.E. Trimble. Railway Tracks and Track work. 2nd edition of 1908.
or not it is the force actually used to work the signal." *

"One of the most helpful and efficient means for safely handling a large number of trains over the same track is a good block system." #

"The electric semaphore is the latest development in automatic signals. The admitted deficiencies of enclosed signals and the objections to disks as less distinctive to the eye than the semaphore have led to many experiments with automatic apparatus for working full sized semaphores; and the semaphore worked by an electric motor is now in use on a number of roads. The peculiar advantage of this arrangement that each signal has its own independent motive power, like the clockwork on the rail, while yet the arm is full sized and is moved by such a powerful force that it is unaffected by wind snow or sleet." +

* Block and Interlocking page 28
# Railway Signaling page 72. See acknowledgment.
+ Adams page 140
"The superiority of electricity as a motive power in interlocking work, as well as for a great many other purposes is due to the facility with which it can be stored and retained for indefinite periods of time with very small loss from leakage, and to the small loss in transporting it from the point where it is generated or stored to the point where it is to be used. The conversion of electrical into mechanical energy can be effected with a high degree of efficiency the question of efficiency of conversion being, however of less importance in interlocking work than the high degree of insulation that is possible to attain. The circuits of an interlocking plant can easily be so well insulated that the loss on account of leakage is practically nothing, and faults in insulation can very easily be detected and removed; in fact, immediate attention is called to faults of a serious nature in electric circuits by their interference with the proper operation of the plant."

* Railway Signaling page 38.
"The electric motor semaphore signal has several advantages, among which may be mentioned: (1) localization, it being self-contained, and therefore independent of all other signals; (2) comparatively large reserve power; (3) an isolated plant is not required for its operation; (4) economy of installation and operation; (5) working and control functions are unified; (6) external simplicity of design."

"Of the many signals in use at the present time the semaphore type is undoubtedly the most popular, and the tendency is to adopt this as standard." Standard (13) 499.

"The signal may, however, be operated by means of gas stored in a tank in the base of the signal post. This method of operating signals, however, is not considered as satisfactory as the electrical method."
Standard (13) 503.

In the face of such convincing evidence as cited above there is no reasonable conclusion but that the all-electric automatic block signal system is the best one to use.

† Automatic Block Signals. Scott page 6.
Chapter Two.

Location.
location of signals.

The locations of the signals are shown on the map at the back of this paper. Signals (1), (2), (3), and (4) are already in use and no change in location is necessary.

Approaching St Joseph from Glover the first signal needed is a home signal before entering the side track territory at St Joseph. The home signal (5) is protected by the distant signal (7). Signals (5) and (6) are staggered. Signal (5) need be only a few in advance (perhaps 125 feet) of the switch points and signal (6) only far enough beyond the switch points to give clearance to a train entering either side track. On leaving St Joseph going west signal (9) needs no distant signal because it is in yard territory. It is placed far enough in advance of the switch points (see diagram) to give clearance to a train entering the yard going east.

In general the signals on a single track as here designed shall be staggered. This staggered distance on open track has an economic length even though it is only an added protection.

To place the staggered signals a great
distance (4000 ft.) apart would cause too much delay while a flagman walked to the next signal to ascertain the trouble or to receive orders carried by the opposing train. The minimum distance to stagger these signals is the greater braking distance of a train between these two signals from one direction or the other; for, should an engine man not see the distal indication and see the home signal at stop only when upon it, he would yet have time to stop his train before butting into an engine opposing at the staggered signal ahead. The grade of the track between the two home signals and other factors (see page 35, line 22) should be taken into account in spacing these two signals.

The braking distance of a train is the distance that the train will run after the brakes have been applied until the train comes to a stop. In calculating this distance, there are six factors which must be taken into account. They are: (1) train resistance, (2) grade resistance, (3) the brake resistance, (4) the rate of grade, (5) the total weight of the train, and (6) the velocity of the train at the instant that the brakes are applied.
Braking Distance.

The engine rating west is 1500 tons.
The engine rating east is 1600 tons.

Having given the above data it is a simple computation to find the braking distance. The problem can be solved by the application of the work and energy formula \( W = D KE \), that is the work done is equal to the increment of kinetic energy. To find the work done:

- \( A \): the weight of the train in tons times the train resistance in pounds per ton.
- \( B \): the brake resistance in pounds per train.
- \( C \): the grade resistance for a one per cent grade times the rate of grade, times the weight of the train in tons.

A distance on a given grade may begin unless the braking distance is all on a constant grade. This distance, which is known is \( D \).

- \( S \): the braking distance of the train.

\( A, B, D \) and \( S \) are always positive. \( C \) may be positive or negative.

Then the work done on a constant grade is equal to \( S(A + B + C) \).

\[ (1) \]

The increment of kinetic energy is \( \frac{1}{2} MV^2 \), where \( M \): the mass (weight/322),
and \( V \) = velocity of the train in feet per second. Mix expressed in feet per second. (II)

Combining (I) and (II), the braking distance is \( S \). 

\[
S = \frac{1}{2} MV^2 (A + B + C)
\]

\( S \) is an unknown distance and is the braking distance.

If the braking distance extends beyond a break in grade, \( D \) must be brought into the equation, and the work side of the equation must be broken up into parts.

There are nine conditions under which the braking distance will vary. They are, (1) on a level track, (2) on a positive grade, (3) on a negative grade, (4) on two or more positive grades, (5) on two or more negative grades, (6) on a level and a positive grade, (7) on a level and a negative grade, (8) on a positive and a negative grade, (9) on a negative and a positive grade.

Numbers (6), (7), (8), and (9) may be modified according to the grades. That is, in (6) the level and the positive grade might not be long enough to get the braking distance in. The next grade would then need to be considered in order to calculate correctly the braking distance of a train.
As an illustration of the above principle note the following problem: A train whose total weight is 1800 tons is running at a velocity of 40 miles per hour at a distance signal. The home signal is 1848 feet or a 0.0 percent grade, in advance of the foot of a 4.74 percent grade. How far back on the 4.74 percent grade must a distant signal be placed so that the train can come to a stop at the home signal?

Data:
1. Train resistance equal 4.6 pounds per ton
2. Grade resistance equal 2.0 pounds per ton or a 1.0 percent grade.
3. The brake resistance for the train is 90,000 pounds.

Solution:

\[ W = a k_e \]

The first part of the equation is divided into two parts, that for a 0.0 percent grade and that for the 4.74 percent grade.

Part 1.
\[ A = 1800 \times 4.6 = 8280 \text{ pounds} \]
\[ B = 90000 \text{ pounds} \]
\[ C = 0 \]

\[ F_i = (A + B + C) = \text{force in pounds} = 98280. \]
\[ D = 164.8' \]
\[ 98280 \times 164.8 = 161,965,440 \text{ pound feet} \] (III)
Part 2.

\[ A = 1700 \times 4.6 = 8280 \]

\[ B = \frac{2700}{90000} \]

\[ C = \frac{1}{2} (20 \times 0.74 \times 1800) = \frac{1}{2} \times 26640 \text{ See figure next page.} (IV) \]

F2: When C is positive \((A + B + C) = 124920 \text{ pounds} \) (V)

F3: When C is negative \((A + B + C) = 71640 \text{ pounds} \)

The second part of the general equation is \( \frac{1}{2} MV^2 \).

\[ M = 3600 \text{ lbs.} / 32.2 = 111800 \text{ gals pounds} \]

\[ V = 40 \text{ M.P.H.} \text{ which is equal to} \]

\[ \frac{40 \times 5280}{60 \times 60} = 58.6 \text{ feet per second} \]

\[ \frac{1}{2} MV^2 = \frac{1}{2} \times 111800 \times 58.6^2 = 191960000 \text{ ft-lbs} \] (VI)

Combining (III), (IV) and (VI) there results

\[ 161965440 + 124920 \times S = 191960000 \] (VII)

\[ S = \frac{(191960000 - 161965440)}{124920} = 242 \text{ feet.} (III) \]

Combining (III), (V) and (VI) there results

\[ S = \frac{(191960000 - 161965440)}{71640} = 419 \text{ feet} \] (IX)

Equations III and IV are multiplied by S to get work.

These calculations may be checked by using a formula of uniformly accelerated motion which is \( V_f^2 = 2as + V_i^2 \), where \( V \) is the final velocity, \( V_i \) is the initial velocity, \( S \) is the same as used above, and \( a \) is acceleration in feet per second per second.

To get the acceleration \( (a) \) the formula \( F = Ma \) must be used where \( F \) is the force \( A+B+C \),
(keeping in mind that c may be + or - as it is both in this problem)
It is first necessary to find the velocity at the foot of the 0.74 percent grade working back from the home signal.

\[
\begin{align*}
V & = 2a5 + V_0^2 \\
V & = 0 \quad s = 1648' \quad a = \frac{F}{M} = 982 \frac{80}{111} \times 80 = 0.88 \\
0 & = 2 \times 0.88 \times 1648 + V_0^2 \\
-2900 & = V_0^2 \\
V_0 & = \pm 12700 = +54 \text{ ft per second}
\end{align*}
\]

It is now necessary to find the acceleration on the 0.74 grade. On the - grade it is \(\frac{F}{M} = \frac{71640}{111} \times 80 = 0.642 = a \). On the + grade it is \(12 + 920/111 \times 80 = 1.11\)

For the - grade \(V_1^2 = 2a5 + V_0^2 \quad a = 0.642 \)

\[
2900 = 2 \times 0.642 \times 8 + 586^2
\]

Solving \(2900 - 3434 = 384.5\)

\(s = 419 \text{ feet}\)

For the + grade \(V_1^2 = 2a5 + V_0^2 \quad a = 1.11\)

\[
2900 = 2 \times 1.11 \times 8 + 586^2
\]

\(2900 - 3434 = 222.5\)

\(s = 242 \text{ feet}\)
In the above problem it has been assumed that the brakes were fully applied at the instant that the engine comes to the distant signal. In the following pages it will be shown that this assumption is not safe and that a greater distance should be used.
In this connection I wish to discuss the arrangement of signals to handle the maximum traffic. In the Railway Age Gazette, June 10, 1910, there is an article by W.H. Argenburgh on The Principles Governing the Arrangement of Automatic Block Signals. I quote the following:

"With any arrangement of signals trains running at full speed will be spaced a distance apart (measuring from engine to engine) equal to the length of the block plus the distance from the approach indication (distant signal) to the home signal (usually one block) plus the distance the train will run while the signal arm is moving from the stop to the proceed position, plus the length of the preceding train. Therefore to accommodate maximum traffic of any one class signals should be so spaced that the length of a block (B) that is, the distance between home signals is equal to Br. + T + X. Here Br is the braking distance for a train, T is the distance the train will run at full speed while the engine man is acting on the signal indication, X is a certain factor of safety."
In the discussion of the minimum distance that engines may be apart when running at full speed the factors are:

(1) The length of the block which is $Br + T + x$. The braking distance has been worked out above. $T$ the distance the train will run at full speed while the engineer is acting on the signal indication. The time that it takes the engineer man to act on the signal indication is taken as five seconds. The distance run will be \( \frac{40 \times 5280 \times 8}{60 \times 60} \sim 293 \text{ feet} \). I shall take $x$ as 20 percent of $Br + T$. $Br = 2067 \text{ feet}$, $T = 293 \text{ feet}$. $Br + T = 2067 + 293 = 2360 \text{ feet}$. $x = \frac{2}{10} \times 2360 = 472 \text{ feet}$. The distance, then, between home signals, and in this case the distance the distant signal is in advance of the home signal, is $2360 + 472 = 2832 \text{ feet}$. 

(2) The distance from the distant to the home signal. It is as above 2832 feet.

(3) The distance that the train will run while a signal arm is moving from the stop to the proceed position. The time that it will take for a signal arm to move from the stop to the proceed position is estimated at six seconds. As the home arm and the distant arm must
Each move from the stop to the proceed position the time will be twelve seconds. The distance will be \( \frac{40 \times 5280 \times 1/2}{60 	imes 60} = 704 \text{ feet} \). (4) The length of the preceding train is in this case assumed to be 1628 feet.

Summing (1), (2), (3) and (4) the minimum distance between engines running at full speed is 2732 + 2732 + 704 + 1628 = 7796 feet.

In this connection it may be said that fast and slow trains, and trains of different length must be carefully considered. In case of a four-track road where freight is handled on two tracks, and passengers on the other two tracks, the signals would be very differently spaced on the respective tracks.
Location of Signals. Continued.

From this digression I now return to the location of the signals as shown on the drawing.

Should two trains approach signal (11) and (12) respectively they would both be warned at the distant signals (13) and (14) to stop at the home signals. If for any reasons it were not possible for one of the trains to stop in the specified distance (between distant and home signals) it may overrun the home signal. The distance that the two signals (11) and (12) are spaced with out danger to either train.

The territory between Mayview and the Urbana slopes is similar to that between St Joseph and Mayview and needs no comment.

In locating signal (25) care was taken to place it far enough in advance of the summit to allow a train to get completely over the summit before it would have to stop. The velocity of a train as it passes the summit will not be great. The location of distant signal (27) depends upon the velocity at its location and hence the question arises: What is the proper velocity to use in the calculation of the braking distance?
The answer is: Use the velocity given on the virtual profile of the line at the point where it is expected that the signal will stand. The virtual profile is the true profile of the line for operating purposes as distinguished from the nominal grade shown by the plotted profile. If the velocity head of the train should be plotted at each break in grade, and these points connected by straight lines, the curve thus drawn would be the virtual profile.

No signal is located where it would stop a train at the foot of a positive grade. Signals (28) and (29) are located where they are, primarily, to give protection on the curve, each being on the straight track to which it will give warning. The approaching engineer has a clear view of the signal for a distance exceeding 2000 feet.

As signals (28) and (29) are in yard territory there is no need for them to be other than two position signals. All home signals are guarded either by distant signals or by being in yard territory and hence none of the signals need be other than two position signals.

*The virtual profile for the fastest train should be used.*
Overlaps

The system of overlaps shown on the tracing at the close of this paper has been carefully worked out.

"With a block section extending from A to B, a track circuit for, say, 2,000 feet beyond B is arranged, so that when it is occupied by a train (or car) the signal at A will be held in the stop position, the same as though the train were between A and B. Thus, when signal A is cleared a train passing it is not only assured of a clear block to B, but also is assured that signal B may be overrun 2,000 feet without danger of collision with a preceding train. From signal Dictionary under overlap.

One feature of the overlap system shown above is to give preference to east-bound traffic, as inspection will make it clear.

An other feature is that the overlaps are arranged so that the engineer may see the distant signal clear. To do this the clearing section of the home signal is extended beyond the distant signal a definite distance. This distance depends upon the time it takes two signals to clear.
and the time that it takes the engineman to act on the signal indication. It takes six seconds to clear one signal, as has been noted above, and it takes five seconds for the engineman to act on the indication. The distance that the overlap controls beyond the distant signal is then 
\( \frac{40 \times 32 \times 172}{60 \times 60} = 1007 \) feet. This control is accomplished by putting an insulated joint and either a track battery or a track relay at the end of the control. Signal (5) shows no overlap beyond its distant signal (7). To maintain the idea that an engineman should see the signal clear an insulated joint would be placed 1007 feet beyond the distant signal (7). A relay or a track battery would be used on either side of the joint. This discussion would not necessarily apply if maximum traffic were under discussion.

For a scientific treatment of principle involved with a graphic solution of spacing problems see an article in the August issue of The Signal Engineer for 1911, entitled: The Arrangement of Automatic Block Signals, written by W. H. Arkenburgh.
Circuits

The control circuits are simple normal danger circuits. An east bound train passing signal (9), for example, would short circuit a track relay (4), and through a back contact of an armature or relay (4), a circuit (not) would be completed through the armature, through the front contact of one armature of every track relay along the track until the east end of the control for home signal (6) is reached, thence by common to the mechanism of home signal (6), and through the battery of signal (6) to the back contact to the point of beginning. Because of the completion of this circuit the home signal (6) will clear. All distant signals are operated by the making of a circuit by the action of the home blade in clearing. This circuit is carried by live wire from the circuit breaker at home signal, through the battery and mechanism of the distant signal, by live wire back to the circuit breaker.

The method of controlling distant signals is shown for distant signal (6). A turnout is put in between signals (6) and (8) to illustrate the method of taking care of turnouts automatically.
A circuit breaker may take care of any number of line circuits. Special attention is called to the closed control circuits of the dotted house signals (1) and (2). Signal (30) and (31) are operated by means of normally closed control circuits although not shown.
Chapter Three.

Construction.
Construction

The different parts which go to make up a complete block signal are so varied that it is not in the interests of economy to have a signal company furnish and install all of them. The parts of the system such as the relays, batteries, or the switch instruments may each be furnished by separate companies.

For the present purpose it is assumed that the railroad company builds all the foundations for the masts, furnishes and strings all line wire, makes it convenient for the signal company to bond the rails at stations, insulates all switch rods and rail joints, place road bed in condition for the proper operation of track circuits, provide permits for buildings, and trenches across streets and high ways, provide work train and crew for distribution of material, tools and men over its own lines, permit the use of hand cars and meloipodes over its lines, stating conditions under which they may be operated, furnish special long ties in place where necessary for application of switch instruments, and permit the signal company to place material in freight houses in reasonable quantities during the progress of the work.

It is further assumed that the Hall Signal
company shall furnish and install all
the fixtures not called for in the above para-
graph.

The following table is an estimate in de-
tail, so far as it seems practicable to go, of the
cost of the system. An account of the indef-
initeness of the profile, alignment, and track-map
it is impossible to locate the exact position of
the signals in regard to stations, turn-outs,
curves, and so forth. In keeping with this data
at hand the following table is to represent the
method of presenting a proposed layout.

The prices are from data in The Signal
Engineer, Volume 4, Number 11, November, 1911.
Table giving approximate estimate of cost of the proposed block signal system between Slouren and Cam-  
phagen on the Cleveland Cincinnati Chicago and St. Louis Railway

<table>
<thead>
<tr>
<th>Number of Units</th>
<th>Unit</th>
<th>Cost Per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Signal (Home and Distant)</td>
<td>$0.50</td>
<td>12.00</td>
</tr>
<tr>
<td>28</td>
<td>Relay</td>
<td>$7.50</td>
<td>210.00</td>
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<tr>
<td>28</td>
<td>Relay box and post</td>
<td>$1.80</td>
<td>51.80</td>
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<tr>
<td>28</td>
<td>Labor setting relay box and relay and wiring for same to track.</td>
<td>$14.00</td>
<td>392.00</td>
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<tr>
<td>53</td>
<td>Battery Chute</td>
<td>$2.25</td>
<td>630.00</td>
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<tr>
<td></td>
<td>Material</td>
<td>$10.50</td>
<td>556.60</td>
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<tr>
<td></td>
<td>Labor setting chute, trunking, and wiring for same</td>
<td>$16.25</td>
<td>861.25</td>
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<tr>
<td>31</td>
<td>Circuit breaker</td>
<td>$1.76</td>
<td>45.12</td>
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<tr>
<td>43.19</td>
<td>Mile of line wire in place</td>
<td>$2.05</td>
<td>86.38</td>
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<td>39.50</td>
<td>Bond wire</td>
<td>$0.05</td>
<td>1.95</td>
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<td>7.90</td>
<td>Channel-pin</td>
<td>$0.08</td>
<td>0.65</td>
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<td>12.34</td>
<td>Bonding per mile</td>
<td>$1.60</td>
<td>19.20</td>
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<tr>
<td>4</td>
<td>Electro mechanical slot</td>
<td>$1.76</td>
<td>14.12</td>
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<tr>
<td>31</td>
<td>Lightning arrester</td>
<td>$0.80</td>
<td>4.80</td>
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<tr>
<td>25</td>
<td>Signal foundations</td>
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<tr>
<td>25</td>
<td>Batteries</td>
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<td>4.75</td>
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<tr>
<td>25</td>
<td>Trunking 50 per signal @ 0.05 cts per foot</td>
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<td>123.4</td>
<td>Stakes 28 per mile @ 0.16</td>
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<td>123.4</td>
<td>Labor setting stakes per mile</td>
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<tr>
<td>496</td>
<td>Foot No. 8 rubber covered wire</td>
<td>$0.03</td>
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<td>496</td>
<td>Foot No. 6 bore copper wire</td>
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<td>525</td>
<td>Yard Concrete for foundation of relay boxes</td>
<td>$3.50</td>
<td>875.00</td>
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<td>28</td>
<td>Paint, tape, solder, and nails per track section</td>
<td>$5.25</td>
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<td>123.4</td>
<td>Cost per mile is $2,157.00</td>
<td></td>
<td>$2,662.00</td>
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THE END
Detail Map
Showing Proposed Block Signal System Between
Cleveland and Chicago on the
Cleveland, Cincinnati, Chicago and St. Louis Railway.

Explanation
Station ()
Home Signal (H)
Distant Signal (D)
Shifted Signal (S)
Central (C)
Circuit Breaker (B) Note: No signal is used.

Typical Track and Control Circuits.