DESIGN FOR AN INTERLOCKING PLANT AT CHAMPAIGN, ILLINOIS

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Introduction

History.

The history of interlocking in the United States dates back to the year 1875 when the first interlocking plant was put into operation at East Newark, New Jersey. The machine used in this plant was manufactured by the Saxby and Farmer Co. In the next few succeeding years the increase in the use of interlocking was rather slow, but in the past ten years it has been quite rapid.

The adoption of interlocking systems by the railroad companies of this county was as much for the purpose of economy as for the protection of the travelling public. Their use became necessary at large terminals because without them the cost of having switches and signals thrown by hand became excessive. The interlocking systems also removed the danger of collision from imperfect hand-signaling during foggy weather. Furthermore they were installed at grade crossings in order to avoid making the required
stop and thereby gain time, and also to save the cost of the stop at the crossing.

The Champaign Crossing

There are several reasons which favor the installation of an interlocking plant at Champaign, Ill. Probably the most important one is that the three railroads that run through Champaign cross each other within a distance of one hundred feet. This would call for a much more simplified plant than one that would be necessary if the crossings of the roads were quite a distance apart. The heavy traffic on two of the roads also warrants the use of an interlocking system at the crossing, not only for the purpose of safety but also for economy of operation. The topography of the land in the vicinity of the crossing also tends to favor the adoption of such a system. The land surface at this point is very nearly level and a grade crossing is almost a necessity, since the cost for grade separation would be very expensive. Still another condition that favors an interlocking system at this crossing...
is that the depots of the three roads are only about a quarter of a mile therefrom, which means that all trains on these roads would have two stops in a very short distance provided there was no interlocking plant.
Location and Description of Site.

The interlocking plant designed in this thesis is to be located at the crossing of the Illinois Central, Big Four, and Wabash Railroads at Champaign, Ill. This line of the Illinois Central is known as the "Main Line" from Chicago to New Orleans. The Big Four line is a part of the Cleveland, Cincinnati, Chicago and St. Louis Railroad, and is known as the "Peoria and Eastern." The Wabash line is a branch line of the "Wabash Railroad System" and extends from Champaign, Illinois, to Sidney, Illinois, a distance of twelve miles. The crossing of these roads is approximately seventeen hundred feet north of the Illinois Central railroad depot at Champaign, and about the same distance east of the Big Four and Wabash railroad depots. There is a fill of about ten feet which extends on the three roads about five hundred feet each side of the crossing. No buildings on private property are nearer to the crossing than five hundred feet.
Alignment of Roads.
The three roads cross each other at practically 90°, the Big Four and Wabash railroads being approximately parallel to each other. The Illinois Central railroad is a double-track line, while the Big Four and Wabash railroads are single track lines. All the roads are on tangent at the crossing. The bearing of the Illinois Central railroad is North 17°38' East. The track of the Big Four railroad east of the crossing makes an angle of 91°22' with the tracks of the Illinois Central railroad north of the crossing. The Wabash railroad crosses the Illinois Central railroad at a point 94.5 feet south of the Big Four railroad crossing. The angle between the Wabash railroad west of the crossing and the Illinois Central railroad north of the crossing is 94°40'. North of the crossing the Illinois Central railroad is on tangent and also south of the crossing for about 1800 feet. At this point there is a 0°30' curve to the east. The Big Four railroad is on tangent for over a mile east
of the crossing, and for about 2600 feet west of the crossing also. On the Wabash railroad there is a slight curve to the south about 400 feet east of the crossing. From this point on this road runs parallel to the track of the Big Four railroad, the distance between the two tracks being 43 feet. About 800 feet west of the crossing there is a short curve on the Wabash railroad to the north, and about 800 feet further on there is another curve but to the south. From this point the track continues on tangent for about 800 feet. There is a "Wye" track connecting the Wabash and Illinois Central railroads, also one connecting the Illinois Central railroad with the Big Four railroad. The former is used by Illinois Central trains running over the Champaign and Havana Line, which extends west of Champaign. These trains run over the Wabash railroad track for a distance of about 2000 feet. A spur runs off from this Wye to the plant of the Twin City Ice and Cold Storage Co. The Illinois Central - Big Four railroad
Wye is used almost entirely for a transfer point. A siding parallels this wye joining it at both ends. Sixteen hundred feet north of the crossing is a track leading from the Illinois Central Railroad to the power house of the street railway system of Champaign and Urbana. This track extends beyond this point and connects with the main line track of the Big Four railroad, at a point about 2200 feet west of the crossing.

About 1700 feet north of the crossing is a switch which connects the northbound main track of the Illinois Central Railroad with a spur track which extends south for about 1400 feet. There are three crossovers for the double-track line of the Illinois Central Railroad.

One is just north of the crossing, another is about 1700 feet north of the crossing, while the third is about 1000 feet south of the crossing. About 1400 feet west of the crossing is a switch on the Big Four railroad which connects with two side tracks which extend east about 1200 feet and end as stub tracks. One
of these tracks connects with the street car line on Neil Street. About 2000 feet west of the crossing there is a track leading off from the Big Four railroad and connecting with the "Champaign and Havana Line" of the Illinois Central railroad. The Big Four railroad freight yard in Champaign is to the north of its track and immediately west of Randolph Street. The numerous tracks of the Illinois Central railroad which lead off from that road south of the crossing extend to the roundhouse and shops of that company, which are about 1300 feet from the crossing.

Profiles of Roads.

The profiles of the three roads are nearly uniformly level at the crossing. The Illinois Central railroad tracks for a distance of 400 feet north of the crossing are level. From this point north there is a gradual rise amounting to about three tenths of one percent. South of the crossing there is a gradual rise of the tracks of the Illinois Central railroad for about 700 feet, the steepest gradient being about five tenths of one percent.
The track for the next 1400 feet is very nearly level. Beyond this point there is a slight up grade.

The Big Four railroad track for the first 400 feet east of the crossing is on about a two tenths percent down grade. From this point there is a gradual rise, the average grade being about three tenths of one percent. West of the crossing the Big Four railroad is very nearly level for a distance of 500 feet. From this point the grade is ascending, the maximum being about seven tenths percent. At 2100 feet from the crossing there is a break in the grade. Beyond this point the grade rises away from the crossing at the rate of about two tenths percent.

The Wabash railroad track east of the crossing is on a down grade of about three tenths percent for about 300 feet. There is a gradual rise from this point for the next 1600 feet, the maximum grade being about five tenths percent. The next 200 feet is on a down grade of about two tenths percent. Beyond this point there is an ascending grade away
from the crossing of about one tenth percent. The Wabash track for the first 200 feet west of the crossing is on about a three tenths percent down grade away from the crossing. From this point there is a continuous up grade away from the crossing, the average grade being about five tenths percent, and the maximum about one percent.

Traffic of the Roads.

The amount of traffic varies considerably on the three different roads. The Illinois Central railroad has the largest amount of traffic, the Big Four railroad has about one third as much as the Illinois Central railroad, and the Wabash railroad has the least. The Illinois Central railroad has eight passenger trains per day in both directions. It also has three passenger trains per day each way over the Champaign and Havana Branch line. The average number of freight trains per day on the Illinois Central railroad is about twenty-five in both directions. There are also two freight trains per day each way o-
over the above mentioned branch line. The average weight of the main line trains is about two thousand tons, and the average length of freight trains is forty-five cars or about 1940 feet.

The Big Four railroad has five passenger trains both ways daily. The number of freight trains on this road will averaging about eight each way per day. The weight of these trains is about 1300 tons and there are about thirty cars to a train.

One engine does all the work on the Wabash railroad between Champaign and Sidney. There are four daily mixed freight and passenger trains each way over this line. This train generally consists of two passenger cars and the or two freight cars.

Illinois Law Governing Railroad Crossings without Interlocking Protection. Railroad crossings which are not protected by an interlocking system are governed according to the following state law, which is quoted in Hurst's Revised Statutes of the 1908 edition and
is found on page 1675. "All trains running on any railroad in this State, when approaching a crossing with another railroad upon the same level, or when approaching a swing or draw bridge, in use as such, shall be brought to a full stop before reaching the same, and within eight hundred (800) feet therefrom, and the engineer or other person in charge of the engine attached to the train shall positively ascertain that the way is clear and that the train can safely resume its course before proceeding to pass the bridge or crossing." This law became effective July 1st, 1885.

Cost of Stopping Trains at Crossings. The cost of stopping trains at an unprotected crossing having heavy traffic amounts to quite an item in a short time. A. M. Wellington in his "Economic Theory of Railroad Location" gives $0.40 as the average cost for one freight train to stop at a grade crossing. In one year this would amount to $146 for one train a day. The total number
of freight trains per day on all lines crossing at this point is seventy, and the cost for stopping these trains would equal $10,220 in a year's time. Mr. Wellington further discusses the additional cost that will result if the requirement for stopping necessitates the reduction of train loads over a division. He gives $1.90 as the cost of stopping each train due to this fact. This does not include the cost of the direct stop, so the total cost of the stop may amount to $1.90 + $0.40 = $2.30 per train.

Advantages of an Interlocking System

A crossing protected by an interlocking system has a number of advantages over an unprotected crossing. The chief one is the reduction in operating expenses as indicated above in cost of stopping at the crossings. If there is an upgrade on the approaches to the crossing the yearly operating cost will be considerably increased. Especially is this so when the stop makes it necessary to decrease train tonnage rating.

Another advantage of an interlock-
ing system at a crossing is that train crews are relieved of switching within the limits of the system, all the switches being operated by the towerman.

The greatest advantage of an interlocking system is the safety that it affords. The switches, signals, and derailers of the roads using the crossing are 29 interlocked in the interlocking tower, that it is impossible to have a collision at the crossing.

Different Types of Interlocking Systems

There are four general types of interlocking systems in use on railroads in this country at the present time. They are as follows: mechanical, electric, pneumatic, and electro-pneumatic. The difference between these different systems is the power that is employed to move the various switches, derailers, signals, and locks within the limits of the system.

In the mechanical type of interlocking system, the power employed is manual. The different switches,
Details, signals, and locks are moved by the movement of levers which are grouped in a tower, and are connected with such levers either by lines of pipe or wire. Pipe lines are generally made of one inch iron pipe. They are supported on rollers about two inches in diameter which in turn are supported on posts of either wood, iron or concrete. Each pipe line is connected to its respective switch, derail, or signal by means of cranks moving in either a horizontal or vertical plane as the case may warrant.

It is necessary that pipe lines shall be compensated to provide against lengthening and shortening due to changes in temperature. Compensators are so constructed as to reverse the direction of travel in a pipe line and thus cause expansion or contraction in different portions of a line to neutralize each other. There are several types of compensators on the market. The simplest of these consists of a straight crank. The compensator most generally used is known as the "Lazy Jack" type. This
consists of two cranks one of sixty degrees and the other of one hundred and twenty degrees, the two being connected by a short link.

In the case of wire lines the wires are supported on small rollers which are enclosed in boxing generally 4 x 4 inches in size 20 as to give them proper protection. Sometimes however, no boxing is used. The size of wire used averages about sixteen hundredths of an inch in diameter.

The mechanical interlocking machine which contains the levers is located in a tower the location and height of which is such as to give the best view of the tracks within the limits of the system. The foundation of the machine is usually independent of that of the tower. The machine is manufactured in sections which consist of either four or eight levers. The number of levers required for a plant will determine the size of tower needed.

A. M. Wellington, who was referred to above, gives the following general
English rule regarding their size, namely: "Cabinets shall be 12 feet wide and 6 inches long for each lever employed, plus an additional 6 feet." Machines are built either with horizontal or vertical locking beds. The most common mechanical interlocking machines on the market are the following: Sazely and Farmer, Standard, Johnson, National, and Stevens. Their chief difference is in regard to the locking beds whether they are in a horizontal or a vertical plane. Nearly all of the present day machines have what is known as preliminary locking, that is the locking of all conflicting levers by the latch rod on the lever which is to be thrown. The latch rod is actuated by the latch handle at the top of its respective lever, and it is impossible to throw the lever until the latch rod has been raised.

One of the foremost types of power interlocking systems is the electric. Formerly, all interlocking systems were manually operated, but the
present day large railroad yards and junctions cannot be operated economically by such a system, since it requires a great number of men to operate one speedily. At the present time nearly all of the large interlocking plants are operated by power, chief of which is electricity. The switches, derails and signals in such a system are moved by means of separate motors which are in close proximity to their respective switches, derails, and signals. The motors are generally protected by a hood of sheet iron. The motors for the switches and derails are of about one horsepower, while those that are used in connection with the signals are about one sixth of one horsepower. The current is furnished from a storage battery which is generally located on the ground floor of the signal tower. The battery is charged from a dynamo which is driven either by an electric motor or by a gas engine. The current is conveyed to the motors within the system either on telegraph poles on
the railroad right of way or in box- ing, or by a combination of both methods. The control of the current to the va- rious motors is done thru means of the electric interlocking machine. The pulling of the different levers cause circuits to be made and broken which thus operate the motors at the derailed switches and signals. Electric interlocking machines have either horizontal or vertical locking beds. At the back side of the machine is arranged a series of fuses so that if at any time the current becomes too strong and there is danger of harm to the apparatus, the fuses will burn out and thus break the circuit.

In the pneumatic type of inter- locking the switches and signals are operated by means of compressed air under a pressure of about fifteen pounds per square inch. Each switch and signal has its own separate cy- linder, the supply of air to which is controlled by valves having large
rubber diaphragms and working under a pressure of seven pounds per square inch. The air for such a system is furnished from one or more reservoirs.

There are three pipe lines connecting with each switch and signal. The largest pipe is used to convey the air direct from the reservoir to the working cylinders. Another line is used to carry the compressed air from the reservoir to the valves which operate the cylinders. The third pipe line leads from the cylinders at the switches and signals to the tower and is known as an "indicating" pipe line. The last two mentioned pipe lines are about one-half inch in diameter. Before the air is conveyed from the reservoir to the valves and cylinders, it is passed through a condenser to remove any moisture that is present.

Control of air to the valves at the switches and signals is by means of an interlocking machine placed in a tower. The reversing of a lever in
this machine causes its corresponding valve to move at the switch or signal as the case may be. This movement in turn allows the compressed air to act on the working cylinder and thereby the movement of the switch or signal is effected. The purpose of the "indicating" pipe line spoken of above is to convey to the towerman an indication that the switch or signal has been thrown. The locking in the tower is so arranged that a lever cannot be fully reversed until the indication has been given. The locking bed of a pneumatic interlocking machine is placed in a vertical position, and the levers controlling the valves are located directly above. For all ordinary distances the movement of switches and signals is almost instantaneous with the reversal of their corresponding levers, and for long distances the interval between the two movements is not great enough to be of inconvenience.

In the electro-pneumatic type of interlocking compressed air is
used to move the switches and signals and electricity is employed to control the supply of air for such movements. Air is compressed and stored in reservoirs as in the case of a pneumatic system, and is conveyed to the switches and signals by lines of pipe. To prevent the moisture in the air supplied from condensing and freezing in cold weather in the pipes and valves, the air is passed through cooling pipes. Any remaining moisture in the air is counteracted by alcohol which is placed in the pipes and reservoirs. The movement of the switches and signals is effected by means of cylinders and pistons. The air pressure ordinarily used is seventy pounds per square inch, although any pressure between fifty and one hundred pounds per square inch can be employed. At all switches and signals there are auxiliary air reservoirs so that there will be a sufficient supply of air at all times to insure the quick action of the piston in the
cylinder. Admission and exhaust of air at the cylinders is controlled by electromagnetic valves which are operated by an electric current either obtained from primary or storage batteries or from a generator. The control of the electromagnets is effected by means of wires which connect them with the interlocking machine in the tower.

The interlocking machine for an electro-pneumatic plant is similar in many respects to those employed in an all-electric system. In the type of machine under discussion the levers are quite short and are light as their only function is to open and close electric circuits and to operate what mechanical interlocking is necessary. They stand in a vertical plane, and to operate them it is only necessary to turn them either to the right or left, the angle described being about sixty degrees. The locking bolt is horizontal as in an electric machine. At the back of the machine are a set of fuses whose function is to
prevent the electric current from becoming too strong and thus endangering the mechanism at the signals and switches.

The operation of switches and signals in a plant of this kind is as follows; when a lever in the machine is reversed it completes an electric circuit. The current is conveyed to the switch or signal as the case may be by a wire which magnetizes the electromagnet at this point and an armature is drawn to the magnet as is also a valve which is attached to the armature. This movement of the valve allows the compressed air, which is under a pressure of seventy pounds per sq. inch, to enter the working cylinder and act on the piston. The movement of the piston throws the switch or signal. The switch or signal is thrown back to its original position by throwing the same lever in the tower back to its normal position. The action at the switch is the same as above stated with the exception that the
air is now admitted from the other end of the cylinder. This necessarily reverses the motion of the piston which in turn throws the switch to its original position.

Advantages and Disadvantages of Each Type.

The chief advantage of a mechanical interlocking system is that it is the simplest of the four different types discussed above. It can be operated and repaired by men of average skill. Its chief disadvantage is that it cannot be operated for distances much greater than 2000 feet. Also it is not well adapted for large yards and busy junction points since in such cases a large number of men would be required to operate the levers so that there will be no delays.

The electric system of interlocking has many advantages and few disadvantages. One great advantage of this system is that the size of the system is not limited and as a result the entire system can be operated
from one central tower. Another advantage is that the mechanism for throwing switches and signals is located at each switches and signals and thus all trouble resulting from defects in pipe and wire lines is eliminated.

Another advantage of this system is that one towerman can do the work of about five men in a similar mechanical plant. The disadvantages are that the machine is complicated and a skilled electrician is needed to make what repairs are necessary. The first cost is also higher and not justified in small plants.

The pneumatic type of interlocking has the following advantages; the extent of the system is not limited, the throwing of switches and signals is almost instantaneous with the reversal of the levers in the tower, it can be used at large terminals and crossings, and as in the electric system all working mechanism is located at the switches and signals. Its disadvantages are that a constant
supply of compressed air has to be furnished, and that moisture has to be removed from the air by means of condensers.

The electro-pneumatic system of interlocking has about the same advantages and disadvantages as does the pneumatic system. One additional advantage however, is that by using electricity for the control of the air, the system is made more positive in its action. One disadvantage other than those given under the pneumatic system is that it is necessary that a regular supply of electricity be furnished.

State Laws Governing Interlocking Plants

The first state to create a railroad commission for the regulation of railroads was Massachusetts. The commission was formed in that state in 1869, and two years later in 1871 a similar commission was formed in Illinois. It was not many years after this that all the important states

of the Union had their railroad commissions. In Canada the first board of railroad commissioners was organized in 1888. The laws made by these different commissions in regard to interlocking systems vary considerably. A summary of the Illinois law in regard to the installation of interlocking systems is as follows:

1) Railroads using the crossing can jointly draw up their plans and present the petition for interlocking to the commission. (2) When the two roads can not agree on a system, either road may petition the commission. (3) If the commission considers a crossing unsafe it may compel the railroads using the crossing to give an answer why the crossing should not be protected. (4) An interlocking plant having been decided upon, the commission has power to approve the plans presented, to examine the plant in operation to see if all requirements are fulfilled, to give a permit for operation.
The Illinois Railroad and Warehouse Commission has thirty-four rules at the present time in regard to the installation and operation of interlocking systems. Below is a summary of these rules which can be found in the 1910 report of that commission.

I. Before the erection of an interlocking system is undertaken a series of plans of the proposed plant should be filed with the secretary of the commission for approval or amendment. The plans must show all tracks within the limits of the proposed system and any buildings which tend to obstruct the view of the tracks. The plans must also show the proposed location of all switches, points, signals, derails, etc., with their relative distances or else a plan drawn to scale should be submitted. The grades of all tracks also must be shown and the direction of traffic on such tracks.

II. A petition for the inspection of a completed system must be accompanied
by a plan similar to that described in
I and must show the system as completed
III. A complete diagram of locking
must accompany the petition for inspec-
tion.
IV. A manipulation chart must be
furnished with the petition for in-
spction.
V. If the system is complicated rules
for the guidance of railroad employees
shall accompany the above petition.
VI. All signals must be so con-
structed so as to go to the danger
position by gravity if the connection
to the tower should become broken.
VII. The home signals should not be
less than 50 or more than 200 feet in
advance of the point it governs. When
in the danger position the arm shall
be horizontal. In case more than two
arms are employed, the upper one
should control the main or high speed
route. In mechanical systems the
home signals may be operated by either
a pipe line or two wire lines.
VIII. All distant signals should
be at least 1200 feet in advance of the home signal. It must be interlocked with the home signal and must be operated by two lines of wire.

IX. Diver or hot signals should only be used as switch indicators, operating with a switch.

X. Dwarf signals should be used only to govern movements on secondary tracks or on main line tracks against the current of traffic.

XI. Bracket posts should be used where it is necessary to signal trains moving on parallel tracks in the same direction, from one post.

XII. Towerman must be able to see all signal lights. When the front light cannot be seen a back light must be provided.

XIII. All fixed lights in the interlocking tower must be screened so engineers will not mistake them for signal lights.

XIV. Derrails in high speed tracks must be at least 500 feet in advance of the crossing on level track, and when
there is a descending grade toward the crossing they must be placed at a greater distance so as to give the same measure of protection.

XV. Derails on secondary tracks must be placed so as to afford as much protection as is required for high speed tracks.

XVI. Where a secondary track crosses a high speed track derails should be placed each side of the crossing on both tracks.

XVII. Where two secondary tracks cross each other derails should be placed on both tracks each side of the crossing.

XVIII. Derails should be placed on all sidings some distance back from the point where they join a main line track.

XIX. Back-up derails on double track should be not less than 200 feet or more than 300 feet from the crossing.

XX. For mechanical plants all derails and switches must be worked by
pipe line not less than one inch in diameter.

XXI. Slip switches, movable point frogs, and derails should be locked by connections separate from those used to move such slip switches, frogs, and derails.

XXII. Switch movements shall be located on solid foundations and tie plates and tie straps shall be used in this connection.

XXIII. All track fixtures used in changing the route of trains shall be provided with detector bars at least 50 feet in length. Electric detector circuits may be installed in place of detector bars when the railroads using the crossing have efficient help so that these circuits can properly be attended to.

XXIV. Detector bars shall be required at the crossing when the consulting engineer deems it advisable.

XXV. Levers shall be grouped in a tower and should be so arranged that those of any certain combination...
are near each other.

XXVI. The interlocking machine should be equipped with preliminary locking.

XXVII. The locking of levers must be so arranged that the towerman could in no way organize a collision.

XXVIII. Signal towers should be so located and should be of such a height as to give the best view of the tracks and signals.

XXIX. All pipe lines shall be provided with sufficient compensators to provide against expansion and contraction due to temperature changes.

XXX. Suitable foundations must be provided for pipe compensators and cranks.

XXXI. Where an interlocking system is complicated by the presence of crossovers, turn-outs and other connecting tracks, the same measure of protection must be provided throughout the system as is provided at the crossing.

XXXII. Inspection of the plant by the consulting engineer of the
commission will not be made until the entire system is completed and in working order. Furthermore, the inspection will not be made until all the above requirements have been fulfilled.

XXXIII. A railroad company wishing to alter the design of a completed plant, for which a permit to operate has been granted, must present a new petition before the commission with plans showing the proposed changes. If changes are made in the original plant, as accepted by the commission, before a second permit is granted for the proposed changes, the original permit will be forfeited.

XXXIV. All railroads operating interlocking plants by permit of the commission shall each month make a report to the consulting engineers of the commission in regard to the condition of the plant. History of the Present Plant at the present time the
crossing is protected by an electric interlocking system. The plant was erected by the General Railway Signal Company of Rochester, New York in the winter of 1904 and 1905. The work of installation was begun in December of 1904 and the plant was completed in March of the following year. The Railroad and Warehouse Commission of Illinois granted a permit for its operation on May 11th of the same year.

The electric current for the system is obtained from fifty-five storage cells of two volts each. This gives a current of one hundred and ten volts for the motors at the switches and signals. The cells are suspended from shelves which are located on the ground floor of the signal tower. This tower is just west of the Illi-
nois Central railroad tracks and between those of the Big Four and Wabash Railroads. The cells are charged every week by a generator which is run by a gasoline engine.

On the top floor of the signal tower, which is a building fourteen and one half feet square, is located the interlocking machine. The machine has a capacity of thirty-two levers, but only twenty-three are in use at the present time. The locking bed is horizontal and is protected by a glass cover. Only two tower-men are needed to operate the system, one working during the daytime and the other at night.

The first cost of the plant was $12,000. The Illinois Central Railroad paid three-fifths of this amount, while the Big Four and Wabash Railroads each paid one-fifth. The division of cost was made according to the number
of levers for each road. About ten day's work per month is needed to keep the plant in proper working order, and the cost for such work is about $50 per month.

The present plant is quite efficient and meets all the requirements for which it was designed. No accidents have occurred between trains of the same road, or between those of the three roads, within the limits of the system since the plant was placed in operation. One or two minor derailments have occurred where engineers have run through open derails.

Proposed Mechanical Plant

In working out the design of this plant it was necessary that a number of drawings should be made. They will now be referred to. Plate I gives the alignment of all the tracks of the three railroads in the vicinity of the crossing. It is drawn to the scale of 100 feet to the inch. Besides showing all the tracks it gives the location of all the derails
and signals of the present electric interlocking system, and also the location of all streets. All distances noted are measured from the intersection of the south-bound main track of the Illinois Central railroad and the main line track of the Big Four railroad.

Plate II gives the profiles of the three roads. The alignment of each road is also given below its respective profile. The horizontal scale used was 100 feet to one inch and the vertical scale was 2 feet to the inch.

Plate III gives the alignment of the three roads with the proposed mechanical plant installed. In other respects it is a duplicate of Plate I.

Plate IV gives the locking sheet of the plant. This shows how the different levers are interlocked in the locking bed in the tower.

Plate V is the dog chart constructed according to the requirements of the locking sheet of Plate IV.

Plate VI is the manipulation
chart. It gives the order the levers shall be reversed in order to set up any route desired.

Adaptability to Present Alignment, Grades and Traffic.

A mechanical plant could be operated to good advantage at this crossing since the alignment of the tracks of the three railroads is such as to favor such a system. The Illinois Central and Big Four railroads are tangent a long distance each side of the crossing and there would be no friction in pipe and wire lines resulting from curves. On the Wabash railroad there is a slight curve of a few hundred feet east of the crossing, but this fact would not have much weight in determining the type of system to be installed.

The number of switch tracks, crossovers and wye tracks are of no hindrance to the establishment of a mechanical plant at the crossing, since the number of levers that would be required for such would not be too
many for one man to easily operate.

The grades of the three railroads each side of the crossing offer no objection for the installation of a mechanical interlocking plant. They are practically level and sufficient protection can be obtained within the maximum operating distance of such a system.

The location of the depots of the roads, which are all about 1600 feet from the crossing also tend to favor a mechanical plant. Trains arriving at the crossing whether leaving or entering Champaign will be going slower than would be the case if the stations were further from the crossing, since outgoing trains will not have gotten up much speed and incoming trains will have begun to check their speed before reaching the crossing.

The amount of traffic on the roads tends to favor a mechanical plant, since it is not so great but that one man can easily operate such a plant.
Maximum Distance Mechanical Plants can be Operated.

It has been found from experience that 2000 feet is about the maximum distance that a mechanically operated signal can be worked. This is due to the fact that for distances greater than this the strength required to reverse the lever is greater than that possessed by the average man. Therefore in the design of the plant undertaken, this fact has been recognized and the system designed accordingly.

Equipment of Proposed Plant

Main Line Derailes

All the roads will be provided with two main line derailes. For high speed tracks with nearly level grades these must be at least 500 feet from the crossing as is stated in rule XIV. All derailes will be of the switch point type. The one on the Illinois Central Railroad north of the crossing and on the southbound main track shall be placed 500 feet from said crossing and will be so placed as to derail a
train to the west. The derail south of the crossing on the north-bound main track of the same road shall be located 600 feet from the Big Four crossing, which will make its distance from the Wabash railroad 505.5 feet. This derail will be placed 20 as to derail trains to the east.

The derails on the Big Four railroad, both east and west of the crossing, shall be located 500 feet therefrom. Both will be placed 20 as to derail trains to the right.

The derail on the Wabash railroad east of the crossing shall be located 500 feet therefrom, and will be placed 20 as to derail trains to the right. The one west of the crossing will be located 350 feet therefrom and will derail trains to the right. As the Wabash train approaches this point at a low rate of speed this line would not be considered as a high speed line and therefore is not subject to the limit stated above. To place it west of the Illinois Central-Wabash railroad wye would probably
cause the tracks of both roads to become blocked in case a derailment occurred.

Back-Up Derails.

Two back-up derails shall be used for the double-track line of the Illinois Central railroad to protect the movements of trains against the current of traffic. Both shall be of the switch point type. One will be located on the north-bound main track of this road at a distance of 150 feet from the crossing. This will be placed so as to derail a south-bound train to the left. The other derail shall be on the south-bound main track and at a distance of 250 feet from the Big Four railroad crossing and 155.5 feet from the Wabash railroad crossing. This derail shall be installed so as to derail north-bound trains to the left.

Home Signals.

Each road shall be provided with two home signals and they shall be located within the limits set by rule VII. All shall be located on the
right-hand side of the track they govern, and all shall be placed 11 feet from the center of the track with the exception of the one on the Big Four railroad west of the crossing, which shall be 10 feet out in order to allow for proper clearance for a side track. All home signals shall be connected with the tower by two lines of wire. The blades on all of these signals shall have square ends.

The home signal on the Illinois Central railroad north of the crossing shall be located 50 feet in advance of the derail. It shall consist of two blades, the top one governing the main line and the lower one the siding that leads off to the right. Joint south of the Wabash crossing. The home signal on the same road south of the crossing will be located 11½ feet in advance of the derail. This signal shall have only one blade.

On the Big Four railroad the home signal each side of the crossing shall be located 50 feet in advance of the derail
Both of these signals shall be equipped with one blade.

The home signal on the Wabash railroad east of the crossing shall be located 50 feet in advance of the derail. The one west of the crossing shall be located 200 feet in advance of the derail. This signal shall have two blades, the top one governing the movement of Wabash trains, and the lower one controlling the movement of Illinois Central trains around the urge.

Distant Signals.

There shall be one distant signal for the Illinois Central railroad, and it shall govern the movements of south-bound trains. There is no necessity for a north-bound distant signal on this road. One reason is that the station of this road is only 1600 feet from the crossing. All passenger trains stop at Champaign, and since the track is on tangent between the depot and the crossing, the home signal will be sufficient to inform the train crews whether the crossing is clear for the passage of their train. Another
reason why a distant signal is not needed is that the speed of north-bound freight trains past the depot is slow, probably not exceeding ten miles an hour.

The Big Four railroad will be equipped with distant signals on each side of the crossing. The one east of the crossing is necessary for both passenger and freight trains. The one west of the crossing is for freight trains since they seldom ever stop at Champaign.

There shall be only one distant signal on the Wabash railroad and this one shall be located east of the crossing. A distant signal is unnecessary west of the crossing since Wabash and Illinois Central trains approaching from the west move at a low rate of speed.

In determining the location of distant signals use has been made of an article which appeared in the Signal Engineer under the title of "The Scientific Location of Distant Signals." In this article 2810 feet is given as the distance a freight train travelling fifty miles an hour.

*See Signal Eng. Sept. 1910 Article by J. G. VanZandt, U. of Ill
will travel on the level after the brakes have been applied, and therefore this should be the minimum distance between the home and distant signals. This is figured on the basis of "80 per cent light weight braked" and cars averaging fifty tons loaded, 90 per cent "good brakes" and air pressure of 70 pounds per square inch. For grades the author makes a statement after the following manner. That on grades between level and .5 percent, about 110 feet should be added to the 28½ feet on downgrades for each one-tenth percent of grade, and for upgrades about 80 feet should be subtracted from 28½ feet for each one-tenth percent. A chart is also given in the article which gives the distance of the distant signal from the home signal for different rates of grade. Distances are plotted as ordinates and grades both ascending and descending as abscissae, the curve passing thru the point where the 28½ foot distance line and the level grade line intersect.
The above information was used only in determining the location of the distant signal on the Illinois Central railroad north of the crossing, since on the Big Four and Wabash railroads the speed of trains is limited to much less than 50 miles an hour because of the large number of street crossings in Champaign crossed by these roads. The location of the south-bound home signal on the Illinois Central railroad has been stated above to be 550 feet from the crossing. The average grade from the home signal north is plus .3 percent, or on the approach a minus .3 percent. Therefore the south-bound distant signal on the Illinois Central railroad shall be located 550 + 2810 + 3 x 110 = 3690 feet from the Big Four crossing. As this distance exceeds the maximum distance a mechanically operated signal can be worked, this signal will be operated in connection with the electric block signal system of this road.

The distant signal on the Big Four
railroad east of the crossing shall be placed 2100 feet therefrom. This distance is sufficient since the downgrade toward the crossing is light, and the speed of trains at this point is never greater than thirty miles per hour. The distant signal on this road west of the crossing shall be located 2400 feet therefrom. As explained above this is only for the accommodation of east-bound freight trains, and since these trains pass this point with a speed not greater than twenty miles per hour, this distance will be sufficient.

The distant signal east of the crossing on the Wabash railroad shall be located 2100 feet therefrom. The conditions are similar as those on the Big Four railroad opposite this point, and therefore the two signals will be placed at the same distance from the crossing.

Dwarf Signals.

There shall be five dwarf signals employed in this design, all of which are in connection with the Illinois
Central railroad. All shall be equipped with a single arm with the exception of one which shall have two arms. All of these signals shall be connected with the tower by means of wire lines there being two wires for each signal. One of these signals shall be located on the Illinois Central Railroad 270 feet north of the crossing and between the north and south-bound main tracks of that road. This signal shall control movements over the crossover and south-bound movements over the north-bound main track.

Another signal shall be placed 600 feet south of the crossing and between the north and south-bound main tracks. It will govern movements of trains westward over the Illinois Central–Wabash Railroad wye and movements northward over the south-bound main track of the Illinois Central Railroad.

A dwarf signal shall be located the same distance from the crossing as the one above, and to the right
of the next track west. This signal shall control trains on this track both in regard to the crossing of this track over the Illinois Central-Wabash wye and the switch connecting this track with the south-bound main track of the Illinois Central Railroad.

Another dwarf signal shall be located on the spur which leads off of the Illinois Central-Wabash Railroad wye and extends to the plant of the Twin City Ice and Cold Storage Company. This signal shall be located 150 feet south of the switch on the above mentioned wye.

The fifth dwarf signal shall be located between the north and south-bound main tracks of the Illinois Central Railroad and 1850 north of the Big Four Railroad crossing. This signal shall consist of two arms, the upper one governing movements of south-bound trains from the north-bound main track to the south-bound main track over the crossover, while the lower arm shall govern the movements of south-bound trains.
from off the north-bound track to the riding on the east.

Main Line Switch and Lock Movement.

7 The switch and lock movements shall be employed in connection with main line switches. They will be operated by pipe lines from the tower and they shall be equipped with bolt locks. Two will be connected with the crossovers on the Illinois Central railroad which is about 1700 feet north of the crossing, one being used at each end of said crossovers. Another switch and lock movement shall be connected with the switch on the north-bound main track of this road which is 17/6 feet north of the crossing. The remaining two shall be used in connection with the crossover on the same road which is just north of the crossing.

Main Line Facing Point Locks.

The number of facing point locks for main line switches shall be eight. All shall be connected with the tower by two lines of wire. One facing
point lock shall be located at the
switch on the south-bound track of
the Illinois Central Railroad which
is 1600 feet north of the crossing. An-
other shall be placed at the switch
on the south-bound main track of this
road which is 736 feet north of the
crossing. Another facing point lock
shall be connected with the switch
on the south-bound main track of the
Illinois Central Railroad just south
of the Wabash Railroad crossing. Still
another lock on this same track shall
be located at the point where the
Illinois Central - Wabash Railroad
wye leaves the above mentioned track.
Another facing point lock shall be
located at the point where the spur
track from the Twin City Ice and
Cold Storage Co. joins the Illinois
Central - Wabash Railroad wye.
Another lock shall be at the point
where the above mentioned wye track
joins the main line track of the Wa-
bash Railroad. This point is 445 feet
west of the crossing. The two remain-
ing facing point locks shall be located on the Big Four railroad. One shall be 730 feet west of the crossing at the west end of the Illinois Central-Big Four railroad wye, and the other shall be placed 1359 feet west of the crossing at a point where a siding connects with the main line.

Facing Point Locks for Main Line Derails

All main line derails, whose location has been described above, shall be locked by means of facing point locks. This will require eight locks one being placed at each derail. All shall be connected with the tower by two lines of wire.

Switch Movement for Secondary Track

All secondary track switches connecting with main line tracks shall be of the split switch type and shall be locked with facing point locks, with the exception of the switch on the spur track which is east of the Illinois Central railroad north-bound main track and north of the crossing. This switch shall be locked with a switch and
lock movement since it is a trailing point switch. All the above switches shall be operated from the tower by means of pipe lines. The facing point locks shall be connected with the tower by two lines of wire. Derail for Secondary Tracks.

All derails on secondary tracks with the exception of one, shall be of the type that sets over the top of the rail. These shall be connected with the switch points by pipe lines. The number of this type of derail will be seven. The derail on the track leading off of the south-bound main track of the Illinois Central railroad at a point 1600 feet north of the Big Four railroad crossing, shall be located 200 feet from the switch on the main line. Another derail shall be placed at the north end of the Illinois Central - Big Four railroad wye. It shall be located from the switch which connects this wye track with the south-bound main track of the Illinois Central railroad. The derail on
the spur track east of the north-bound main track of the same road shall be placed 200 feet from the switch which connects this track with the main line. Another derail shall be located on the track that leads off of the south-bound main track of the Illinois Central railroad 84 feet south of the Wabash railroad crossing. It shall be located 200 feet south of this point. A derail shall also be placed on the spur track leading to the plant of the Twin City Ice and Cold Storage Co. It shall be located 140 feet south of the switch connecting this track with that of the Illinois Central - Wabash railroad wye. Another derail shall be placed at the west end of the Illinois Central - Big Four railroad wye. It shall be located 100 feet from the switch which connects this track with the main track of the latter road. Still another derail shall be located on the siding which connects with the main track of this road at a point 1359 feet from the crossing. It
shall be placed 95 feet from the main line switch.

The derail on the first track west of the south-bound main track of the Illinois Central railroad and south of the Illinois Central-Wabash railroad wye shall be of a different type from the above. This derail shall be of the switch point type. There is a great deal of switching on this track due to the fact that it leads to the Illinois Central railroad roundhouse and shops. Therefore to secure better protection to trains using the Illinois Central-Wabash railroad wye, this type of derail shall be used. It shall be located 430 feet south of the Wabash railroad crossing and shall be connected directly with the signal tower by pipe line guard rails.

All the main line tracks shall be equipped with guard rails at the derail. At the back-up derail on the Illinois Central railroad north of the Big Four railroad crossing
The guard rail shall extend from said derail toward the crossing a distance of 125 feet. At the back-up derail south of the Wabash railroad crossing on this same road, the guard rail shall extend from said derail toward the crossing for a distance of 50 feet. All other guard rails shall extend from their respective derails a distance of 300 feet toward the crossing.

Detector Bars.

As required in rule XXIII detector bars shall be employed at all derails and switches. This requires that 29 bars shall be used. In all cases, whether at a derail or switch, they shall be 50 feet in length and shall be placed in advance of the points. They shall be made of steel and shall be 2 1/2 inches wide and 1/2 inch thick. All detector bars shall be placed on the outside of the rail, and in the case of curves they shall be placed alongside of the outer rail. When the levers connected with such detector bars are in their
normal position the top of the bars shall be 1/4 inch below the top of the rail. When the levers are being reversed the bars must rise at least 3/4 inch above the top of the rail. The connection pieces with the pipe levers shall be made as nearly parallel to the track as possible.

Crossing Bars

Crossing bars shall be used at the crossings. They shall be of the same size and shape as the detector bars described above and shall answer to the same requirements. Six of these bars shall be used at the Big Four-Illinois Central railroad crossing and five at the Wabash-Illinois Central crossing.

Machine

A safety and farmer interlocking machine shall be used. It shall be of the preliminary latch locking type and shall have a horizontal locking bed. There shall be 59 working levers and 9 spare levers, making the total number 68. All shall have an
equal and uniform throw. All levers shall be numbered from left to right and shall be painted as specified in rule XXV. The machine shall be supported on foundations which are independent of those of the tower tower.

The tower shall be located on the east side of the Illinois Central railroad tracks and midway between those of the Big Four and Wabash railroads. It shall be 14 x 34.5 feet and shall be 10 feet from the centerline of the northbound main line track of the Illinois Central Railroad. The tower shall be of sufficient height so as to give the towerman an unobstructed view of all the tracks within the limits of the system.

Leadout

The rocker shaft type of leadout shall be used. All shafts shall be of steel and two inches square. The leadout must be 20 constructed that rise pipe and four wire lines can lead off to the north along the west side of
the south-bound main track of the Illinois Central Railroad, and so that rise pipe and rise wire lines can lead off to the south on the west side of the same track. This will require that the rocker shafts shall be run under these tracks. The rest of the pipe and wire lines shall lead off on the east side of the Illinois Central railroad tracks. All parts of the leadout must be securely fastened to leadout timbers by ¾ inch bolts.

Pipe Lines.

All pipe lines shall be made of iron pipe one inch in diameter. They shall be run parallel to the main line tracks and shall be 4.5 feet from the nearest rail and spaced 2 ¾ inches center to center. They shall be 20 laid and connected that they will lead off to the different switches in order.

Twelve pipe lines shall run north along the east side of the Illinois Central Railroad's north-bound main track. At the two crossovers one pipe line shall operate the
two switches. Eleven pipe lines shall run south along the east side of the same track. Three pipe lines shall run east along the south side of the Big Four main line track. Six lines of pipe shall run west along the north side of this same track. Three lines of pipe shall run east along the north side of the Wabash railroad track and six pipe lines shall be run along the same side of this track west of the crossing. This makes the total number of pipe lines connected with the tower as forty-one, and a total length of 24,740 feet including about 600 feet of pipe line not directly connected with the tower.

Pipe Carriers.

The anti-friction type of pipe carrier shall be employed. The foundations of the carriers shall be of concrete and they shall be spaced every seven feet. The top of the foundations shall be one inch below the level of the base of rail. The number of carriers required are as follows: 4-15 way,
5-14 way, 2-12 way, 26-11 way, 9-10 way, 15-9 way, 44-8 way, 184-6 way, 179-4 way, 4-3 way, 257-2 way, and 17-1 way.

Pipe Connections.

The sections of pipe lines shall be connected by standard pipe couplings. They shall be so located that when the levers are on center they will be at least 12 inches from the pipe carriers.

Pipe Conduits.

Pipe conduits shall be employed to protect the pipes which cross under tracks and road crossings. They shall be made of two-in galvanized iron pipe. They shall be provided with stuffing boxes at each end and shall also have an oil inlet. This will require a total length of galvanized iron pipe of 2455 feet.

Turns in Pipe Lines.

Turns in pipe lines shall be made by means of horizontal cranks. They shall be supported on concrete foundations. The ninety degree standard crank can be employed at all turns.
and therefore will be used. The number of cranks required is thirty-one.

Pipe Compensators.

Pipe lines shall be compensated with horizontal one way "Lazy Jack" compensators having one sixty-degree and one one hundred and twenty-degree arm. The distance between center of pin holes shall be 22 inches, and the crank arms shall be 11 x 13 inches. Concrete bases shall be provided. The number of compensators of the above type employed shall be twenty-four.

Wire Lines.

The wire lines shall be of unannealed galvanized steel wire .15 inch in diameter and shall be in coils of not less than 2,500 feet. Two wires will be used to operate every signal blade. The wire lines shall be placed alongside the pipe lines. Jumps in wire lines shall be made by means of chain wheels. The total length of wire required is 33,870 feet.

Wire Carriers

The wires shall be supported
on small rollers which are held within a carrier frame. The foundation of the pipe lines will also serve as a support for the wire carriers. The carriers shall be spaced 21 feet apart and the number shall be as follows: 42 - 6 way, 198 - 4 way, and 266 - 2 way.

Chain Wheels

Chain wheels for turns in wire lines shall be horizontal, of cast iron and 10 inches in diameter. The number required shall be as follows: 6 - 4 way and 13 - 2 way.

Tie Plates

Three tie plates shall be employed at all derails and switches and shall be placed as follows: one on the point tie and one on the nearest tie or either side. They shall be of the same type as is employed on other portions of the track. The number required shall be sixty-three.

Tie Straps

Tie straps shall be used at all switches and derails. These straps shall be of iron, one half inch thick and
two and one half inches wide. They shall be placed on the top outer edge of the ties and fastened by lag screws. The number of tie straps required shall be forty-two.

Cost of Material.

The cost of material required is as follows:

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Probable Cost of Maintenance

In determining the probable cost of maintenance use has been made of
an article which was read at the convention of the Railway Signal Association at Buffalo, N.Y. in 1906 by J. A. Peabody, Signal Engineer of the Chicago and North-Western railroad. In this article is given the cost of maintenance per year for different crossing outlays of mechanical plants. The average cost is about 5 percent of the total first cost. Therefore for the plant designed the yearly cost of maintenance will be about 5 percent of $16,300 or $815.00.
Bibliography.

1. Railway Signal Association’s Signal Dictionary
2. Wellington’s “Economic Theory of Railroad Location” Chapter XXV
3. Kent’s Revised Statutes
4. Illinois Railroad and Warehouse Reports
5. Raymond’s “Elements of Railroad Engineering” Pages 124-129
6. Railroad Gazette Vol. 38, page 335
7. Railway Signal Association Report, 1908, p. 257
### LOCKING SHEET

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(Plate IV)
### MANIPULATION CHART

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