FOR OFFICIAL USE

H8

PW—H8

Post Office Engineering Department

TECHNICAL PAMPHLETS FOR WORKMEN

Subject

Power Circuit Guarding

ENGINEER-IN-CHIEF'S OFFICE
1919

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CORRECTION SLIP TABLE

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		on date:	by (initials):

POWER CIRCUIT GUARDING

(H 8)

The following pamphlets in this series are of kindred interest:

H. 1. Open Line Construction. Part I.

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(27929) A*

POWER CIRCUIT GUARDING

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POWER CIRCUIT GUARDING

1. DANGERS TO BE AVOIDED

Electric Lighting and Power circuits, whether overhead or underground, are a possible source of danger to telegraph or telephone* circuits in the immediate neighbourhood, and the objects of protection are threefold, viz. :—

(i) To safeguard the Department's officers (workmen and operators) and subscribers.
(ii) To safeguard the Department's plant (which includes apparatus and buildings).
(iii) To safeguard the public.

The precautions which are effective for (i) will usually provide for (iii) also.

(i) **Danger to Department's Officers and Subscribers.**—If precautions are not taken at points where telegraph wires and power circuits are liable to get into contact, there is the possibility that workmen handling the wires may receive dangerous electric shocks and injury by falling from a pole as a result of the shock. Moreover, operators handling pegs and keys may receive shock, and possibly any person using a telephone on the circuit at the time.

In this connection alternating current is more dangerous than direct current, it being found by experiment that the physiological effect of the two is, roughly, as two to one with the same voltage—or, put another way, that the effect of a given voltage with alternating current will be produced by a direct current of twice that voltage.

The danger of shock depends, firstly, upon the path of the current through the body; secondly, upon the resistance of the body; and lastly, upon the state of health of the person receiving the shock.

People have been killed by currents of relatively small voltage—200 volts to earth—but the conditions have usually been favourable to the current.

Sixty-five volts alternating and 130 volts direct current are the maximum voltages which can be taken as safe for handling.

(ii) **Danger to Department's Plant and Buildings.**—The Department's wires, cables, and telegraph and telephone apparatus are not designed to carry heavy currents or high voltages, and as a result of contact with a power circuit, wires and apparatus may be damaged by the passage of heavy currents overheating the wires, or the insulation may break down with the excessive voltage. Fires may be started from these happenings which may involve plant and buildings.

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* Throughout this pamphlet electric lighting and power wires are referred to generally as "Power wires," and the term "telegraphs" includes telephones.

(iii) **Danger to the Public.**—Where telegraph wires cross or can be blown into contact with power circuits in the event of breaking, members of the public may be injured by touching a broken telegraph wire, as by reason of the contact with the power circuit the telegraph wire becomes charged to a dangerous potential. Primarily the Ministry of Transport in the case of traction systems and the Electricity Commissioners in the case of electric light and power systems are responsible for securing the safety of the public, but the Department is equally concerned as the owner of the telegraph wire. In passing it should be remarked that members of the public have been killed by touching telephone wires which had fallen across inadequately guarded tramway trolley wires and electric lighting wires.

2. POWER CIRCUIT SYSTEMS

It will be convenient to divide power circuits into three groups, corresponding to the three main uses to which they are put in commercial pursuits, viz. :—

(a) Circuits for Electric Tramways (Page 4).
(b) Circuits for Electric Railways (Page 8).
(c) Circuits for Electric Light and Power (Page 10).

It is not possible to give here a full summary of the legal position of these undertakings. Suffice it to say that the owners are usually under obligation to instal and operate their electric systems in accordance with Regulations* made for securing the safety of the public, and that the Post Office telegraphs must not be injuriously affected. Further, in the great majority of cases where the Post Office has telegraphs on public or private property, the owners of the power circuits have to serve notices upon the Postmaster-General before putting up the power circuits, and must carry out any requirements made by the Postmaster-General for the protection of his telegraphs.

The Electricity Commissioners classify electric lines according to voltage as follows :—

Low Voltage.—A voltage not exceeding 250 volts under normal conditions.

Medium Voltage.—A voltage exceeding 250 volts but not exceeding 650 volts under normal conditions.

High Voltage.—A voltage normally exceeding 650 volts.

This classification will be used in these notes.

(a) **Electric Tramways and Light Railways.**—So far as methods of operating are concerned Light Railways are the same as

* These Regulations are prescribed by the Ministry of Transport in the case of Tramways and Railways, and by the Electricity Commissioners in the case of Electric Light and Power Systems.

Tramways. The difference in effect lies in the fact that Light Railways may run partly on private property and through more than one district, and that the promoters have certain facilities for raising money for capital purposes.

There are three systems of electric traction on tramways in this country :—

The Overhead Trolley.

Surface Contact.

Conduit.

The Department is concerned chiefly with the first named as protection is not specially required for the others, which have no exposed electric conductors. Precautions to be taken with underground power mains are common to all systems.

With the **Overhead Trolley System** current at medium pressure (500-550 volts) is supplied to an overhead wire, called a "trolley wire," which is suspended at a height of about 21 ft. 6 in. above the surface of the road. The current is collected and conveyed to the motors on the car by a boom or arm having a wheel which rolls along the charged wire. The trolley wire is either suspended from brackets attached to iron standards or from wires spanning the roadway between two standards. The return for the current is viâ the uninsulated rail to the generating station.

The potential danger to the public and to the Department's officers and plant, where telegraph wires cross or are likely to fall upon trolley wires, is recognised in a Ministry of Transport Regulation, to be observed by the Tramway Authority, which reads :—"If and whenever telegraph, telephone, or other wires, unprotected with a permanent insulating covering, cross above or are liable to fall upon, or to be blown on to, the overhead conductors of the tramways (or railways), efficient guard wires shall be erected and maintained at all such places, provided that this regulation shall not apply to Post Office over-road stay wires or other uncovered wires which are not electrical conductors, where they are earthed at each end to the tramway (or railway) rails." This Regulation has been expanded in an Explanatory Memorandum which gives details of how the guard wires are to be erected. This Explanatory Memorandum may be briefly summarised as follows :—

Guard wires must be of 7/16 S.W.G. or No. 8 gauge; the material of galvanised steel, except in manufacturing districts where such wires are liable to corrosion, and then bronze or hard drawn copper should be used. The guard wires should be earthed at each end and at intervals of not more than five spans. The earth connection should be made by connecting the guard wires to the rails by an insulated copper conductor ; and the resistance should be sufficiently low to ensure that a telegraph wire falling on and making contact with the guard wires and the trolley wire would operate the circuit breaker on the section of tramway.

The rise of the trolley boom has to be controlled so that it will not foul the guard wires.

Where there is a single trolley wire the number of guard wires depends on the angle of crossing. If the angle is between 30° and 90° one guard wire only is provided vertically above and not less than two feet from the trolley wire. If the angle is less than 30° two guard wires are provided not less than two feet above the trolley wire and one on each side of it (*see* Fig. 1).

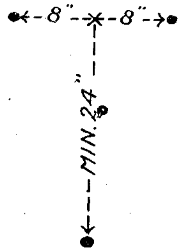


Fig. 1.

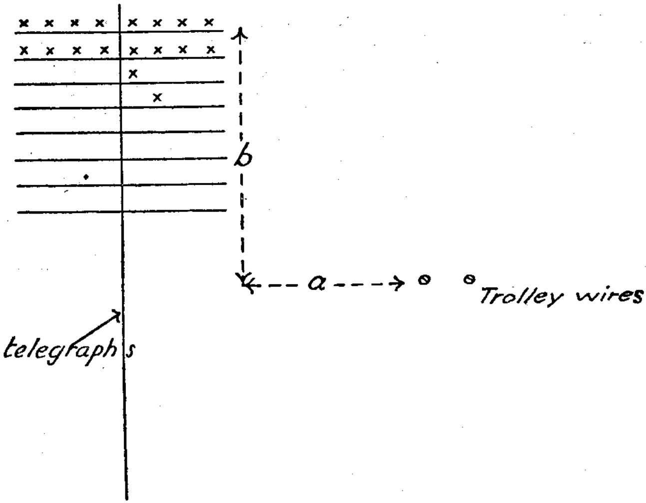
Where there are two or more trolley wires the number of guard wires required and their spacing varies with the weight or gauge of the telegraph wires, e.g. for telegraphs weighing 100 lbs. or more per mile two, three or four guard wires may be required according to the distance between the trolley wires.

Where telegraph wires are parallel to the trolley wire a guard wire should be erected if the conditions fall within the 45 degree rule, that is, where the height above the trolley wire of the highest telegraph wire on the side nearest the trolley wire exceeds the horizontal distance between them (see Fig. 2). In very exposed situations or for heavy routes of wires more than one guard wire may be needed. A "heavy route" has been defined as a line where any of the wires are of greater weight than 400 lb. per mile, or the total number of telegraph or telephone trunk wires is in excess of twenty-four.

Guard hooks have to be provided where it is possible for a telegraph wire to fall on an arm or a stay wire or a span wire and so slide down on to a trolley wire.

* * *

It is not claimed with this system of guarding that contact between a broken telegraph wire and the trolley wires will be prevented in every case. It is possible that contact will be prevented, but if it does take place there is the likelihood that the



Guard when a is less than b.

Fig. 2.

telegraph wire will be burnt through at the point of contact and fall out of harm's way, or failing that, that the circuit breaker on the Tramway System will operate and cut off the current. Experiments have shown that 40 lb. and 70 lb. bronze wires *invariably* fuse at the point of contact. 100 lb. copper sometimes fuses but may carry the current. Heavier gauges of copper do not fuse.

It should be pointed out that guard wires should always be of sufficient size to carry the current likely to occur from contact with the power wires.

In the event of a broken telegraph wire making contact with a trolley wire and at the same time touching a guard wire, the telegraph circuit will not be raised to the normal potential of the trolley wire but to a much lower voltage, depending upon the resistance of the guard wire to earth at this point.

This system of guarding has proved quite satisfactory so far as the Post Office is concerned, but the Tramway Authorities find difficulty in the maintenance of earthed wires so near the trolley wires, and they prefer that insulated wire be used for the telegraph circuits at the danger points, so that guard wires may be dispensed with. This, however, cannot be done usually where heavy gauge trunk telephone and telegraph circuits are concerned, or where the routes of the telegraphs and tramways run parallel. At one time it was the practice, in order to meet the wishes of the authorities, to use rubber covered cables containing from one to four pairs of wires made up with an internal suspending wire. The suspending wire was placed inside the cable for protection as an external bare suspending wire would have necessitated guard wires. It is now the practice to use single wires insulated with paper and covered with cotton wrappings, and a jute or cotton braid specially impregnated with a mixture of litharge and linseed oil, the covered wire being finally passed through a bath of paraffin wax to leave it with a smooth surface. This covering is very durable even in chemically-laden atmospheres, and its insulation has been found to have improved after being erected for some years. This covered wire, called P.B.J., should be erected in short spans only, as the covering increases the weight of the wire, and likewise the surface exposed to the wind. 60 yards should be regarded as a normal span.

With bare wires also it is wise to keep the spans short.

All wires crossing tramways should be erected with a minimum clearance of 28 ft. to the roadway, to give a clearance of roughly 6 ft. to the trolley wire, and 4 ft. to the guard wires.

Trolley booms occasionally get out of control owing to the trolley leaving the wire, and although according to the Ministry of Transport Regulations the rise has to be limited so as not to foul the guard wire, it is found in practice that the regulation rise is often exceeded, and crossing wires are very liable to breakage if a less clearance than 28 ft. above the roadway is given.

Stay wires should not be run across trolley wires when there is any reasonable alternative, and if a crossing is unavoidable some form of guarding should be adopted. The insertion of an Insulator, Stay No. 1 or No. 2 as required, for a $\frac{5}{8}$ or $\frac{7}{8}$ stay wire respectively, between that portion of the stay wire likely to come into contact with a power conductor and that likely to make contact with the telegraphs is generally the best means, but in difficult cases the provision of a wire covered with P.B.J. type of insulation is used as an alternative.

Trackless Trolley System.—There are a few of these systems in the United Kingdom. The essential differences between this system and the ordinary tramway system are the absence of running rails (the cars, within limits, being able to take any course on the roadway), and the use of two trolley wires and, incidentally, two trolley booms, instead of one. The second trolley wire is for the return of the current, there being a + and a — wire, the latter insulated the same as the + wire, except at the negative bus bar, where it is earth connected. The negative trolley being earth connected, it is not necessary to guard against it, as it cannot normally be charged to a dangerously high voltage.

The guarding of the + trolley wires is practically the same as with the ordinary overhead tramway systems, except that the guard wires are connected to the negative trolley wire instead of to earth. It will be seen, however, that unless good insulation is provided on the guard wires leakage is likely to occur from the negative trolley wire, which may in some cases have a fairly high potential (100 volts or more) above earth. It is, therefore, important from the point of view of preventing electrolytic damage that the guard wires should be well insulated and that this insulation should be properly maintained. Fig. 3 illustrates the guarding requirement with a double set of trolley wires up to 15 in. apart.

(b) **Electric Railways.**—There are two distinct types of electric railway systems (i) the **direct current**, and (ii) the **single phase** system.

(i) **Direct Current Railways.**—The majority of these railways are worked at medium pressure (600 volts), but there have been recent innovations of high tension (1500 volts and 3000 volts), and there may be developments of the high tension systems in the future.

The direct current system is generally similar to that employed on Tramways, the outstanding difference being the method of collecting the current. The current is supplied to an insulated rail which runs parallel to the ordinary running rails at a slightly greater altitude. In some cases the current returns viâ the running rails—in which case it is called "the third" rail system, and in others an insulated return (earthed,

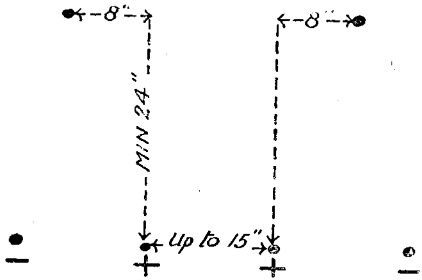


Fig. 3.

however, at the negative bus bar) is provided, two shoes being employed for connection with the live rails. This latter system is called the "fourth" rail system.

It should be observed that, in considering the protection of wires crossing such railways, there is no danger to the ordinary members of the public should a wire break and fall on the railway. A broken wire is also not so likely to touch a live rail as it is to make contact with a power circuit in mid air.

It is the practice on some medium pressure systems for the Companies to place a wooden guard at the side of the live positive rail. These guards are wood planks attached to the live rail and projecting a few inches above the level of the rail.

With the high tension third rail system, the live rail is covered at the top and one side with wood, the shoe on the train making contact on the side of the live rail. It is hardly possible, therefore, for a telegraph wire to make direct contact with the exposed conductor.

In all these rail systems it will be seen that the power rail is only a few inches above the ground, and the return rail (either the running rails or the fourth rail) is similarly situated, and it is practically certain that a broken telegraph wire would make a most complete short circuit of the system, and probably be burnt off. Therefore only the following precautions need be taken :—

(a) **The crossing spans should be as short as possible.**

(b) **The wires should be terminated on each side of the crossings.**

As at all railway crossings, nothing less than 150 lb. copper wire should be employed.

With direct current systems using overhead contact wires with high voltage—1,500 volts and 3,000 volts have been installed—the conditions are much more dangerous, and it is the practice to place all but important telephone trunk circuits underground where they cross such railways. Where important telephone trunk routes cannot be diverted to avoid danger a special guard net is erected between the telephone wires and the contact wires. This earthed guard net is erected as a separate structure from either the railway equipment or the telephone line, and is of stable design and of sufficient surface practically to ensure that a broken wire will not touch the contact wires. It is shown in principle in Fig. 4.

(ii) **Single phase railways** invariably employ extra high pressure—6,600 volts is that in use in this country—with overhead contact wires. With this system practically all circuits endangered should be placed underground. A special net guard on the lines previously referred to would be employed if a case occurred where it was considered essential that an important trunk line must remain open.

(c) **Electric Light and Power Systems.**—A new feature is introduced in the protection of Electric Light and Power Systems. In the case of Tramways and Railways the telegraph wires are *always above* the power circuits, but with these systems the telegraphs may be above or below.

Overhead Power Conductors may be erected only in accordance with the Electricity Commissioners' Regulations. For the purposes of these Regulations, Power Systems are divided into two groups, viz. :—

A. Those in which the voltage does not exceed 650 volts direct current or 325 volts alternating.

B. Those in which the voltage exceeds 650 volts direct current and 325 volts alternating.

The Regulations do not state definitely how guard wires over Post Office lines are to be erected and differ in that respect from the tramway and trackless trolley regulations which have an Explanatory Memorandum. The Section relating to Post Office crossings reads :—"Where a line conductor crosses over or under, or is in proximity to any other overhead wire, precautions shall be taken by the Undertakers to prevent contact, due to breakage or otherwise, between the line conductor and the other overhead wire, or the other overhead wire and the line conductor." In the absence of details as to how this is to be done it is the practice of the Department to define actually its guarding requirements.

Another regulation which is of importance reads as follows :—

Where the pressure to earth exceeds 250 volts direct current or 125 volts alternating current, precautions shall be taken to prevent danger.

(1) from a broken line conductor by the provision of

(*a*) a neutral or earthed conductor carried continuously from pole to pole and so arranged in relation to the other conductors that in the event of breakage of any one of them the line conductor shall make contact with the earthed wire ; or

(*b*) other means approved by the Electricity Commissioners.

Arising out of the provision of the earthed conductor referred to it is the practice to accept this conductor as a guard wire. It is earthed at the station and can normally be charged to a few volts only. Contact of a telegraph wire with the potential wire and the earthed conductor produces a very definite short circuit.

The Post Office guarding requirements, which have been modified from time to time, are set forth in TE 80 (Low and Medium Pressure Circuits) and E-in-C 231A (High-Voltage Power Lines).

In the case of low and medium pressure circuits the chief modifications to the Department's requirements were made in September 1928 when the Overhead Line Regulations of the Electricity Commissioners were revised.

The essential requirements may be summarised as follows :

Guarding is not required for power circuits in which the voltage to earth (or between wires if an unearthed system) does not exceed 60 volts A.C. and 120 volts D.C.

Where these voltages are exceeded guarding is required at all crossings and at every point where the 45° rule is infringed. Fig. 2 illustrates this rule where the telegraphs are higher than the power wires, and it should be noted that a similar rule applies when the power line is higher than the telegraphs.

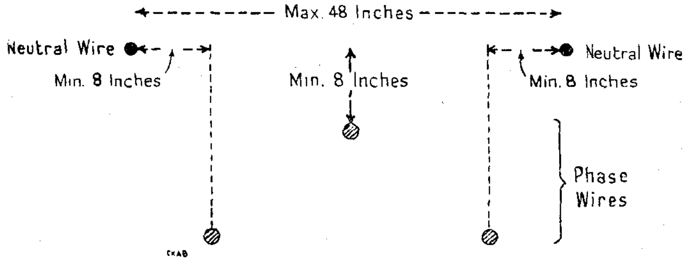

Max. 48 Inches
Neutral Wire
Min. 8 Inches
Min. 8 Inches
Neutral Wire
Min. 8 Inches
Phase Wires

Fig. 5

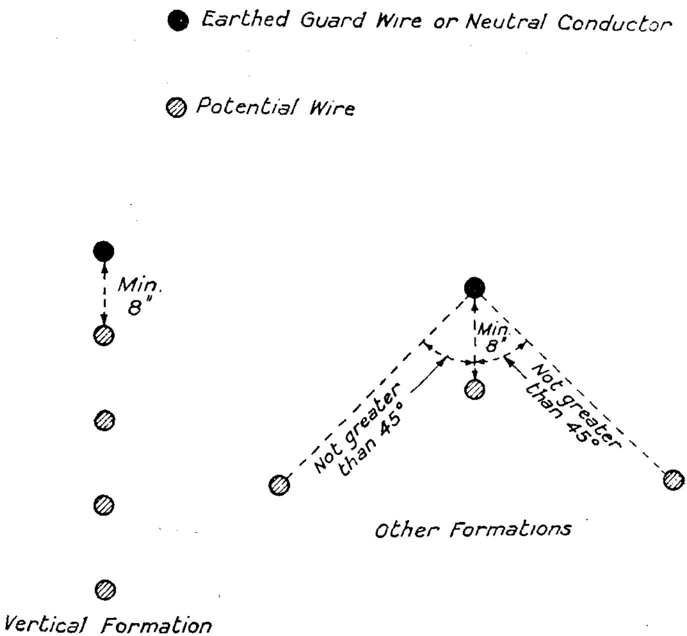

Earthed Guard Wire or Neutral Conductor
Potential Wire
Min. 8"
Vertical Formation
Min. 8"
Not greater than 45°
Not greater than 45°
Other Formations

Fig. 5A.

Four feet is the normal minimum clearance to be allowed between any part of a power line and Post Office telegraphs, but in difficult situations three feet may be accepted. In addition, to enable crossings beneath the Department's wires to be more easily made, two feet will be accepted in cases where the power line supports are placed in such a position with respect to the Post Office wires that there will be no appreciable difference in sag with changes of temperature or under the worst conditions of ice loading. These circumstances will usually occur only at crossings where the power and Post Office poles are in close proximity. There must, however, be no danger to men working on the Post Office poles.

At all crossings under P.O. wires where the Post Office route is not fully developed additional clearance must be provided at the outset to allow for full development.

The alternative methods of guarding are briefly :—

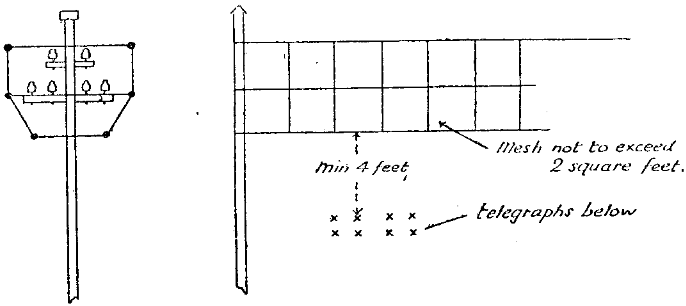


Fig. 6.

(a) **Department's Wires Uppermost.**—Guard Wires over the Power Wires.

Earthed Power Conductors arranged to act as guard wires.

Rubber covered or other insulated power wires with the exception of approved P.B.J. (*see* below) supported by metal ties from an earthed suspending wire.

Power Conductors covered with satisfactory weatherproof insulating material (P.B.J.) where voltage to earth does not exceed 250 volts alternating or 650 volts direct current.

Telegraph wires covered with weatherproof insulating material (P.B.J.).

(b) **Power Circuits Uppermost.**—Cradle guards around the power wires.

Hammock guards beneath the power wires.

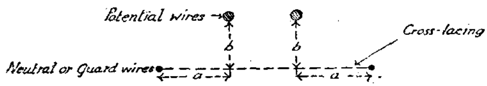
Rubber covered or other insulated power wires with the exception of approved P.B.J. (*see* below) supported by metal ties from an earthed suspending wire.

Power conductors covered with a *satisfactory* weatherproof insulating material (P.B.J.) where voltage to earth does not exceed 250 volts alternating or 650 volts direct current.

Telegraph wires covered with weatherproof insulating material (P.B.J.).

Guard Wires, whether erected with independent earthed wires or by utilizing the earthed power conductors, are arranged with more latitude than on the Tramway Systems. Power circuits are erected with different formations. Sometimes as many as four wires are put up in vertical formation, one above the other. It is not proposed to give all the variations here but the following points are the fundamental considerations :—

The minimum vertical distance between the highest potential wire and the guard wire—or earthed neutral conductor—is 8 inches,



a to be greater than b

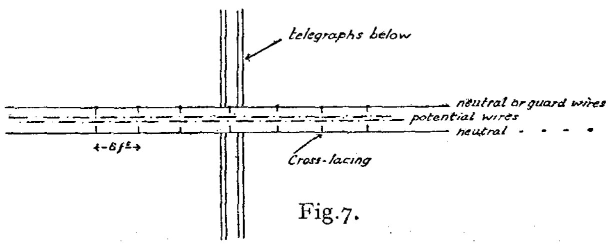


Fig. 7.

Where the telegraphs are uppermost and the crossing is at an angle greater than 30° a single guard wire above the power wires will be accepted. Fig. 5 (*a*) illustrates two typical cases.

Where the angle of crossing is less than 30° two guard wires must be provided, one on each side of the power wires, and they must be placed not less than eight inches outside the vertical plane of the outermost power wires. Fig. 5 shows a typical case.

Rubber-Covered Power Conductors.—The rubber covering on insulated power circuits is not satisfactory as a permanent protection. It usually deteriorates rapidly in the atmosphere, and the owner is generally not much concerned as to whether the covering is maintained properly, as there is no loss of current with deterioration. An earthed suspending wire acts in two ways; it helps to prevent contact, and at the same time calls attention to the necessity of keeping the line insulated, as exposure of the conductors means a loss of current.

Power Conductors Covered with Satisfactory Weatherproof Insulating Material.—These are accepted up to a voltage to earth of 250 volts alternating current and 650 volts direct current. The covering is that used with wires crossing tramways and called P.B.J. It has already been described. (Page 9.)

Telegraph Wires Covered with Weatherproof Insulating Material (P.B.J.).—This has already been described in the section dealing with tramways. (Page 9.)

Cradle Guards around Power Wires.—These may be formed with the earthed neutral wires as the main supports or with independent earthed wires. Fig. 6 is a typical example. The cross lacing is fixed every 6 ft. and continues for 18 ft. on each side of the crossing points.

Hammock Guard.—This is illustrated in Fig. 7. In this case the Potential wires are higher than the earthed neutral wires or the independent earthed supporting wires. The overlap should be greater than the vertical distance between the earthed neutral wire (or earthed guard wire) and the potential wires. The cross lacing should be as with cradle guards.

Power Lines and Telegraphs Parallel.—The 45° rule given in the Tramway Section applies—the conditions being, of course, reversed where the Power line is uppermost. The various methods of guarding described apply as the case may be.

Stay Wires.—The running of Stay Wires under or over power conductors should be avoided if possible. Where there is no alternative, the method of guarding adopted will be similar to that laid down for trolley wire crossings. Where a stay wire crosses above power conductors and the power line poles do not carry an earth wire arranged to afford protection as in Fig. 5A, an Insulator, Stay No. 1 or No. 2 as required, for a $\frac{5}{8}$ or $\frac{7}{8}$ stay wire respectively should be inserted in the stay wire near the Post Office pole. Where a stay wire crosses beneath the power conductor no protection is considered necessary.

* * * *

With overhead systems working at voltages above medium pressure, that is, above 650 volts, it was the practice in the past to agree to various methods of guarding. Cradle guards were accepted for high pressure circuits, and above that voltage Joint Pole construction was the usual method of protection. Experience has shown that these and other arrangements were not altogether desirable, and the practice now is to place either the power line or the telegraphs underground. The rule is that the separating distance shall not be less than the height (measured at the nearest support) of the Power Line (or of any other exposed conductors carrying high voltages) or $1\frac{1}{2}$ times the height of the Post Office line, whichever is the

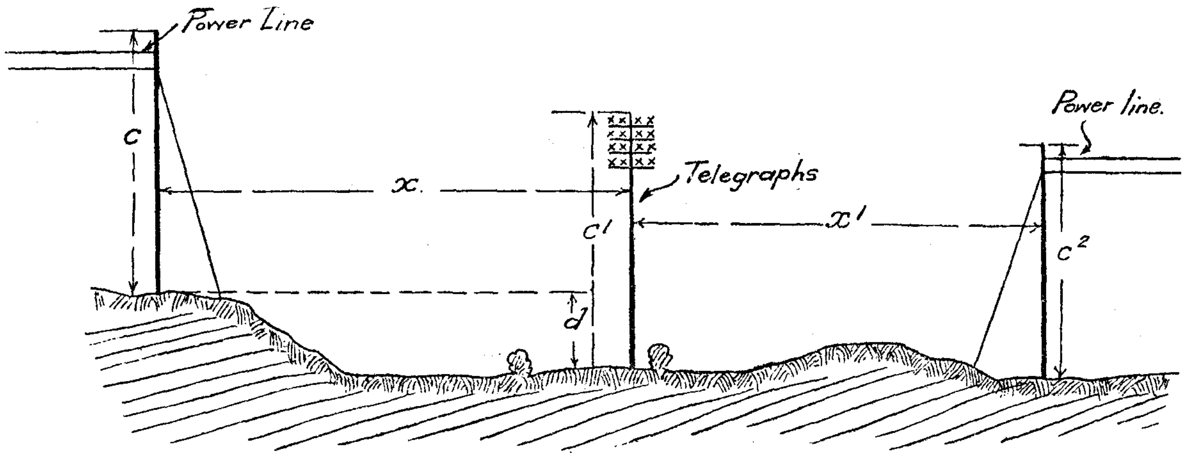


Fig. 8.

$x > 1\frac{1}{2}(c+d) \qquad x' > 1\frac{1}{2}c'$

greater, provided that where the lines are erected on ground at different levels the heights must be calculated from the lower ground level. (See Fig. 8.) The Post Office lines are placed underground if the routes are unimportant and there are no great objections to such a course. Where important telephone trunk circuits are concerned the power line has to be placed underground for the safe distance indicated, except in cases where very high voltages are concerned, when special guarding arrangements are made.

The power line is erected above the telegraphs, double conductors being provided lashed together at 5 ft. intervals and supported by double insulators. In addition a substantial earthed cradle guard encloses the power wires, the guard being erected on supports independent of the power line or on the power line supports if these are of suitable construction.

There are a number of joint poles still in use, and a short description of the structure is as follows: The joint pole is fundamentally an H pole structure to which the power wires and the telegraphs are attached, crossing at right-angles. The power wires are uppermost, passing usually between the two poles, whilst the telegraph wires are attached to arms on each leg of the structure. Between the two sets of wires is a well earthed metal platform made of bar and angle iron. The platform overlaps the telegraph wires by a considerable amount, and iron wings are provided to prevent a broken power wire blowing round the platform. The platform is carefully earthed, and the earth connection wire is insulated and carried in a pipe down one of the poles. The whole structure is well stayed and made as stable as possible. With this structure contact with the telegraphs is practically impossible except by the collapse of the structure.

In some cases on private property a lead-covered cable for the power circuit has been accepted at crossings of telegraphs. A copper strip not less than sixteen thousandths of an inch in thickness is provided under the lead sheath and the cable carried on suspending wires. The lead sheath, copper strip, and suspending wires must be well earthed.

Other methods of guarding have been agreed to in particular cases.

3.—UNDERGROUND POWER MAINS

As great a clearance as is reasonably practicable should normally be given between Post Office cables or conduits and Power Mains, whether of Low, Medium or High Pressure. The two sets of plant should not be laid in contact in any circumstances. In the case of Low or Medium Pressure power cables, the normal minimum separating distance permitted is two inches. Where it is difficult to adopt a separation of two inches, a separation of less than two inches but not less than one inch is permitted, but, wherever the separation is two inches or less, the space between the Power plant and the telegraphs must be filled with a layer of concrete.

In the case of High Voltage power cables the clearance to be provided will depend upon whether the cables are laid as separate single cores or, alternatively, as multiple cores within one sheath. A clearance of at least 18 inches must be provided in all cases where the power cables are of the single-core type. In the case of the multiple-core type the clearance should be at least 12 inches, but, where there is difficulty in providing a clearance of 12 inches, a smaller clearance is accepted on condition that wherever the clearance is less than six inches a layer of concrete not less than two inches thick will be provided.

Wherever a layer of concrete is provided it must overlap the power plant by at least two inches on either side, and, where the two sets of plant cross each other, must be of a length at least equal to the width of the Post Office plant.

4.—FUSES AND HEAT COILS

Fuses and heat coils are placed at the offices in all circuits endangered by power circuits.

The fuses used for this purpose blow with the passage of a current of 3 ampères. Smaller currents, which may not be of sufficient strength to blow the fuse and yet may cause a fire if allowed to flow for any length of time, are dealt with by heat coils which operate at 0·5 ampère flowing from 15 secs. to 210 secs., according to type of heat coil.

The operation of the heat coils cuts off the line from the apparatus, and in the smallest fitting disconnects the line only; whilst with the larger types the line is earthed, and the apparatus either earthed or disconnected.

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LIST OF
Technical Pamphlets for Workmen
(Continued)

GROUP D—*continued.*

18. Distribution Cases, M.D.F. and I.D.F.
19. Cord Repairs.
20. Superposed Circuits. Transformers. Bridging Coils and Retardation Coils.
21. Call Offices.
22. Units, Amplifying. (*Not on sale.*)

GROUP E.

1. Automatic Telephony: Step by Step Systems
2. Automatic Telephony: Coded Call Indicator (C.C.I.) Working.
3. Automatic Telephony: Keysending "B" positions.

GROUP F.

1. Subscribers' Apparatus. Common Battery System.
2. Subscribers' Apparatus, C.B.S. Part 1—C.B.S. No. 1 System.
3. Subscribers' Apparatus. Magneto.
4. Private Branch Exchanges—Common Battery System.
5. Private Branch Exchange—C.B. Multiple No. 9.
6. Private Branch Exchanges—Magneto.
7. House Telephone Systems.
8. Wiring of Subscribers' Premises.

GROUP G.

1. Maintenance of Secondary Cells.
2. Power Plant for Telegraph and Telephone Purposes.
3. Maintenance of Power Plant for Telegraph and Telephone Purposes.
4. Telegraph Battery Power Distribution Boards.

GROUP H.

1. Open Line Construction, Part I.
2. Open Line Construction, Part II.
3. Open Line Maintenance.
4. Underground Construction, Part I—Conduits.
5. Underground Construction, Part II—Cables.
6. Underground Maintenance.
7. Cable Balancing.
8. Power Circuit Guarding.
9. Electrolytic Action on Cable Sheaths, etc.
10. Constants of Conductors used for Telegraph and Telephone Purposes.

GROUP I.

1. Submarine Cables.

GROUP K.

1. Electric Lighting.
2. Lifts.
3. Heating Systems.
4. Pneumatic Tube Systems.
5. Gas and Petrol Engines.