Rail Bonds

and Appliances

Catalogue No. 3

American Steel & Wire Company

Rail Bonds

and

Bonding Appliances

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THIS company maintains a fully equipped bonding department, supervised by able and experienced engineers and manned by competent workmen, which has for many years and with marked success attended to all matters pertaining to bond installations. Through this department we are at all times prepared to install bonds, to make estimates or to advise customers regarding specifications, costs of installations and so on, or to furnish competent supervisors for installations made by the customer himself. Correspondence solicited.

Sales Offices

CHICAGO	72 West Adams Street
NEW YORK	30 Church Street
WORCESTER	94 Grove Street
DENVER	First National Bank Building
SAN FRANCISCO	Rialto Building
BOSTON	120 Franklin Street
CINCINNATI	Union Trust Building
CLEVELAND	Western Reserve Building
DETROIT	Ford Building
LOS ANGELES	Jackson and Central Avenues
MONTREAL	Bank of Ottawa Building
PITTSBURG	Frick Building
PORTLAND, ORE.	Sixth and Alder Streets
SALT LAKE CITY, UTAH	Dooley Building
SEATTLE, WASH.	Fourth Ave. South and Connecticut St.
ST. PAUL-MINNEAPOLIS	Pioneer Press Building, St. Paul
ST. LOUIS	Third National Bank Building
LONDON, ENG.	36 New Broad Street, E. C.

EXPORT REPRESENTATIVES

UNITED STATES STEEL PRODUCTS COMPANY
30 Church Street, New York, N. Y.

Rail Bonds
and Appliances

Catalogue and Manual

American Steel & Wire Co.

Preface

SINCE the edition of our 1907 catalogue, many changes and improvements have been made in rail bonds and bonding tools, and much valuable information has been obtained, so that we are now enabled to present a more complete and useful treatise on this subject.

The purpose of this book is two-fold. First, a systematic and thorough cataloging of all our rail bond products, which have been arranged with a view of rendering the customer all possible assistance in selecting and specifying the material best suited to his requirements. And secondly, to present in serviceable form for all classes of readers, complete and reliable information pertaining to rail bond matters in general.

South Works, American Steel and Wire Company, Worcester, Mass.
The Home of the Rail Bond Factory

Contents

Regarding Orders

TO avoid errors, delays and misunderstandings, purchasers should note the following:

1. Orders and correspondence regarding orders should always be sent to the nearest sales office.

2. In ordering bonds, state capacity, diameter of terminals, distance between centers of bond holes and type, and form number. To enable us to check up orders, we should also know the maker's name and section number of rail and joint plates, also the location of all bolt holes and diameter of bolts.

3. When referring to orders always give the number and date of the order.

4. State distinctly how goods are to be shipped, whether by freight, express or mail. If any special route is preferred it should be mentioned in the order. We reserve the right to route all shipments upon which we pay or allow freight.

5. Before returning tools or material, please secure from us shipping directions.

6. No claims for allowances will be entertained unless made within ten days after arrival of the goods, and no allowance will be made beyond the original invoice price of material.

7. All agreements are contingent upon strikes, accidents or other causes beyond our control.

Part I

General Considerations

General Considerations

THE steel rails of an electric railroad not only serve as track to guide and support the car wheels, but they are also used in general for the return or grounded portion of the electric power circuit. To serve these two functions, the rails have to be joined end to end both mechanically and electrically. In paved streets these two connections are sometimes effected in one operation by welding the rails together, but they are more generally united by the separate use of steel splice bars and copper rail bonds. The splice bars are securely bolted to the abutting ends of contiguous rails to hold them together rigidly and to maintain them in perfect alignment. The splice bars cannot be depended upon, however, to serve as good conductors to conduct the return current from rail to rail, owing to the coating of rust and scale always present on exposed railway steel, which at times effectually insulate the parts. Therefore the rails have to be bonded together electrically with copper rail bonds in a manner which will secure a continuous or uninterrupted metallic circuit having a very low electrical resistance. The continuity of the return circuit is fully as essential to the economical operation of an electric railway as that of the feeder circuit. Rail bonds therefore serve as electrical conductors for bridging rail joints, and they have no other function. (See "Notes on Electricity, page 146.)

The many styles, shapes and sizes of rail bonds shown in Part II of this book are made necessary by the great variety of types and dimensions of rails and splice bars, and by various kinds of track construction. All rail bonds in common use are alike in having some kind of a solid copper terminal connected to each end of a flexible copper conductor. The terminals which serve to make electrical contact with the rail vary greatly in shape and size, depending upon the manner in which they are connected to the rail and upon the carrying capacity of the bond. The style, shape and size of the conductor portion of a rail bond are determined by the particular kind of rail joint to be bonded, by the carrying capacity of the bond, and by the method of applying the terminals to the rails. The useful life of any bond will depend equally upon the integrity of the terminal contact and the power of the conductor wires to withstand the motions of the rail joint.

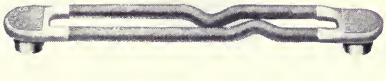
Copper

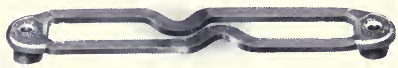
Pure copper such as used in the construction of all our bond terminals and conductors, possesses many physical properties which make it indispensable for rail bond purposes. It has to a very high degree the qualities of conductivity, malleability and ductility. Its strength and hardness are greater than that of any other metal except iron and steel, and when drawn into smaller wire it is extremely flexible. Copper has the power of resisting oxidation, is easily worked and can be forged with less difficulty than iron. Any foreign substance, whether metallic or oxide, alloyed with copper will have a bad effect upon these useful properties. Copper takes a fine polish, and all the rail bonds we make are given, by special processes, a beautiful bright finish which will be retained indefinitely.

Types of Rail Bonds

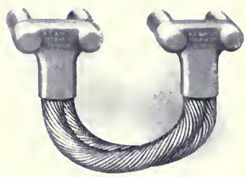
The American Steel & Wire Company manufactures five distinct types of rail bonds, there being many forms and sizes of each, classified as follows:

Crown Rail Bonds Having stud terminals either solid for compression or tubular for pin expansion, the conductors joining the terminals being either single solid copper wires, or strands composed of a number of small round wires. See pages 60 to 75.

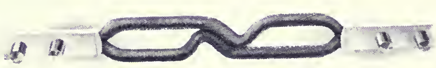




United States Rail Bonds Having single stud terminals either solid for compression or tubular for pin expansion, the conductor being composed of flat copper strips or ribbons laid parallel. See page 76.



Twin Terminal Rail Bonds Having two small parallel studs on each terminal, the conductor between the terminals being composed of a strand of small round wire. See page 52.



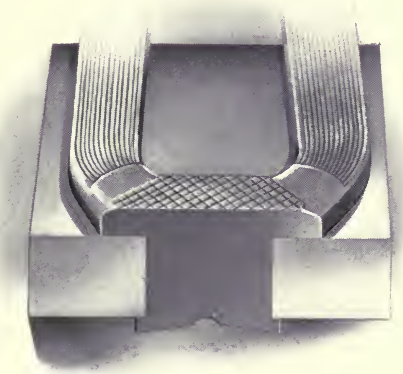
Soldered Stud Bonds Having flat terminals for soldering to the rail, provided with two small integral studs which are expanded into corresponding holes in the rail. This bond has a combination stud and soldered terminal. The conductor is composed either of round wire strand or of flat copper ribbons. See page 56.

Soldered Rail Ronds Having flat terminals. The electrical connection with the rails is made with common solder and the conductor between the terminals is composed either of round wire strand or of flat copper ribbons. See page 58.

Rail Bond Terminals

The cuts show five different kinds of rail bond terminals, differing in form and in method of application to the rail. Of these, three have short cylindrical studs which are expanded into holes drilled in or through some portion of the rail and which make intimate contact with the steel. These terminals are drop-forged from pure rolled copper of highest conductivity. A fourth style is soldered to the rail surface, while the fifth is a combination soldered and stud terminal. Each style of terminal has certain distinguishing features which make it best suited for certain conditions, as will now be pointed out.

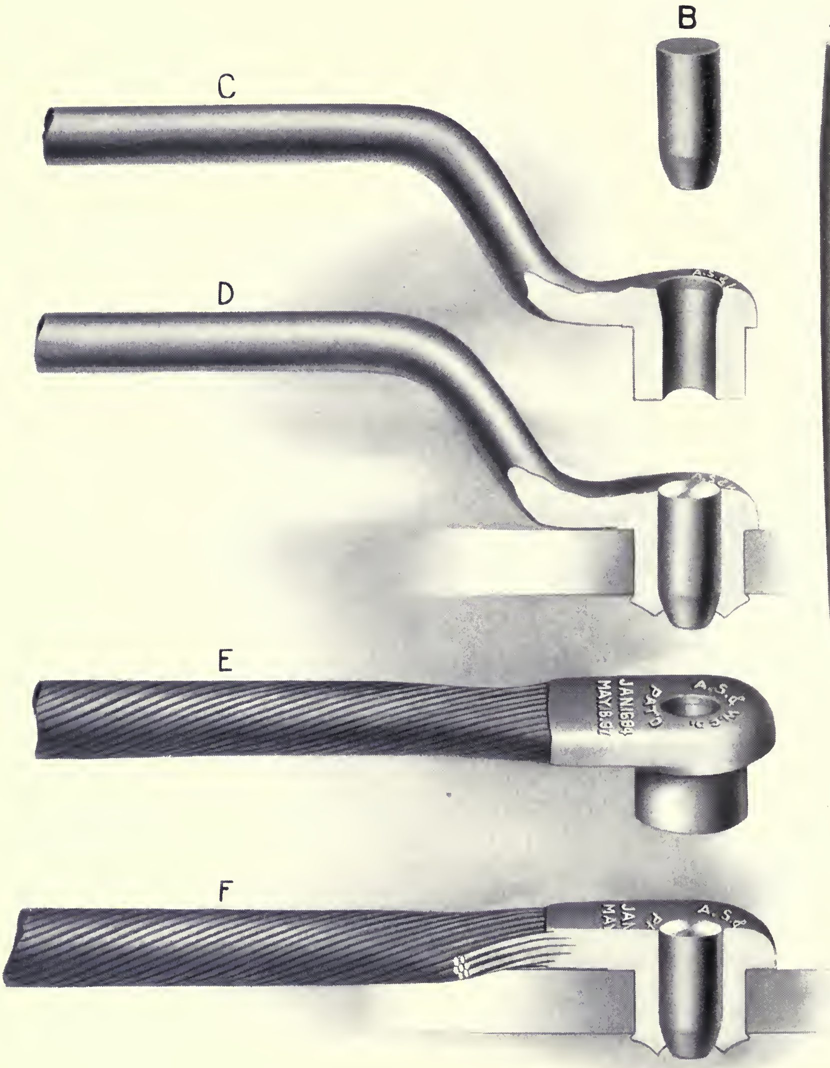
Solid Stud Terminals This style of terminal requires for its application to the web or flange of a rail, the use of some form of powerful screw or hydraulic compressor, such as described on pages 120 to 126. Under a sufficiently and correctly applied compression stress from one of these compressors, a solid terminal stud of pure annealed copper, such as made for the Crown and United States bonds, will expand radially until it presses against the annular walls of the hole in the rail with great force, making an intimate molecular contact that is lasting and high in electrical conductivity. These bonds have at each end a single large solid terminal stud, or two small terminal studs separated 1¼ inches between centers.



Section Through a Solid Terminal

In comparison with the other two styles of stud terminals to be described, the solid stud offers the single mechanical advantage of having a rivet or button head formed against each side of the rail section, which helps to seal the contact and to hold it more securely.

Tubular Terminals These terminals are expanded radially against the walls of holes drilled through the web of rails, by means of tapered expansion punches driven through them. After the terminal is inserted in the hole, a long taper punch (A, next page) lubricated with grease or heavy oil is first driven entirely through the terminal, then a short drift pin B is driven home, as shown in cuts D and F. The diameter of the latter is about $\frac{1}{32}$ inch greater than that of the former. Thus the small drift pin supplements the expansion of the taper punch, while the compressed copper lying between the cylindrical surface of drift pin and the larger cylindrical surface of the hole in the rail, maintains sufficient friction on the pin to



Tubular Terminals

hold it in place. The diameter of the hole through the terminal is thus enlarged about ⅛ of an inch, causing a material displacement of copper. As the metal flows against the wall of the hole in the rail it makes an extremely great pressure and an intimate molecular bearing which ensures a highly efficient and lasting contact. All further expansion hardens the copper and causes a portion in contact with the expanding punch to flow along with it out of the hole, where it expands and forms a burr or rivet head, as shown in cuts D and F.

Rail bonds provided with this style of terminal have several inherent advantages. They can be installed more quickly and economically than the compressed type, as shown on page 38. No special tools are required for their installation, only a taper punch, a drift pin and a heavy hammer. The simplicity of the operation ensures uniformly good results. In the application of this terminal the human element is almost entirely eliminated. All the work can be done from one side of the rail, which is often of advantage in rebonding rails in paved streets and in bonding frogs or other special track construction. If necessity requires, these bonds if carefully removed may be used a second or even a third time. A taper punch and drift pin somewhat larger than used in the first installation will produce the required extra expansion and a perfect contact.

With every tubular terminal bond we ship two steel drift pins without extra charge, and in large orders we supply an extra number amounting to five per cent. We provide hardened steel taper punches, in sizes correct for the terminals in which they are to be used, at moderate prices, which will be quoted upon application.

One taper punch should install from one hundred to two hundred rail bonds. The following table shows the dimensions of taper punches and pins regularly made for different sizes of tubular terminals. The sizes of pins designated as "standard" are those which will be supplied with bonds, unless otherwise specified. Standard sizes are adequate when the bond holes are drilled reasonably accurate to size. Larger pins will be substituted for those of standard diameters, without additional expense, when specified.

Dimensions of Drift Pins and Taper Punches

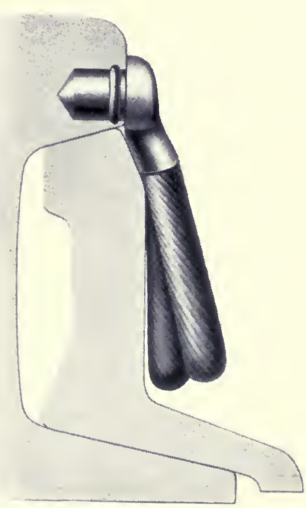
Table I

Terminals			Drift Pins		Taper Punches	
Diameter in Inches		For Size of Bond B. and S. Gauge	Diameter of Pins in Inches		Greatest Diameter in Inches of Standard Taper Punches	Length of Taper Punches in Inches
Outside Stud	Hole Through Terminal		Standard	Special		
1 and over	9/16	. .	21/32	43/64 to 23/32	5/8	5
7/8	13/32	4/0	1/2	33/64 to 9/16	15/32	4
3/4	11/32	3/0	7/16	15/32	13/32	4
5/8	9/32	2/0	11/32	. .	5/16	3 1/2
1/2	2/10	1/0	1/4	. .	15/64	3 1/2

Twin Terminals This style of terminal, as more fully explained on page 52, is provided with two solid parallel copper studs, each one-half inch in diameter by $\frac{9}{16}$ (or $\frac{11}{16}$) inch long. It also has two bosses located axially on the outer side over the studs. The two terminal studs are spaced 1 ¼ inches between centers and are placed into close-fitting bottomed or cup-shaped holes drilled in the outer face of the rail head. The four holes required for a bond are drilled by one of the four-spindle drills described on pages 95 to 105. A shallow annular groove or thread is cut into the wall of each hole near the orifice, as shown. The depth of the holes is equal to the length of the terminal studs, less $\frac{1}{16}$ of an inch. The end of each stud rests upon the bottom of the hole, which serves as an anvil. The soft copper of the studs is expanded laterally by means of hammer blows applied to the bosses on the outer face of the terminal, filling the annular groove and every minute depression in the wall of the hole. The extra length of the studs and the surplus copper in the bosses supply enough extra metal to more than fill the holes. The impact of the hammer on these short studs fills the holes full of copper and causes an extremely great contact pressure between the copper and steel.

Twin Terminal Bond

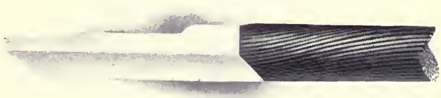
This style of terminal has several advantages peculiar to itself. There is but one possible entrance for moisture to each hole and this is sealed by the ring or thread of copper that forms about each stud as the copper is hammered into the hole. Each stud is securely anchored in the hole. The area of contact is comparatively large. Being sealed against corroding agencies and under great pressure, the contact will remain bright and highly conductive for an indefinite period. The cost of installing this terminal is extremely low. No special skill is required for its installaton.



Section Through Terminal Hole

Soldered Terminals This style of terminal has a plane surface which is soldered direct to the rail. The soldering surfaces are knurled and tinned for purposes of making a better and stronger soldered union to the steel. The durability and electrical conductivity of a soldered contact between copper and railway steel depend to a great extent upon the physical condition of the surfaces as to whether they make uniformly close contact, and whether they are clean and well tinned and free from oxide at the time of soldering. When well made the contact resistance per square inch of surface will be extremely small. The working temperature of the metals, the composition of the solder and of the flux may vary between fairly wide limits without affecting the strength of the joint. A well made soldered contact should last indefinitely unless it is broken by severe jarring of the running rail caused by the hammering of car wheels at the rail joints. (See type B. S. B., next page.)

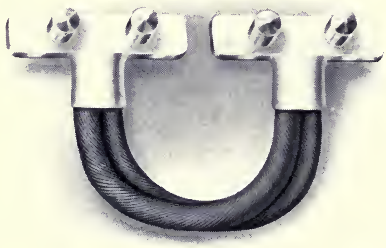
In making a soldered joint, the rail surface to be soldered is first brightened with an emery wheel, such as shown on page 132. The rail is then heated with a double burner brazier (see page 135) until the steel takes on a bright blue oxide. The surface is then quickly tinned by alternately applying a good grade of soldering flux and stick solder. The bond terminals are then fitted closely to the rail so as to make close contact throughout, then clamped in this position. The parts are reheated and treated freely with flux, then wire solder is fed into the space between the surfaces as long as it will take solder. There is no positive assurance of having made a perfect soldered union except by testing it for strength or for electrical resistance. The latter test, which would in no way injure a good joint, is preferable and can easily be made with the Crown Bond Tester shown on page 42.



Type S. B. Soldered Bond

The *Brazed or Welded Terminal* is very similar in form and size to the soldered terminal. The brazing spelter which secures the terminal to the rail differs from solder only in being stronger and in requiring a much higher temperature for melting. It offers no advantage electrically. In making a welded union, the copper is melted and the steel must be brought to an equally high temperature before the two metals will unite. As the melting temperature of copper or brazing spelter is but little below that of steel, a complex and expensive apparatus of some kind is required for heating the parts. Great skill and care of the workmen are required to control this high temperature so as not to injure the steel or burn the copper while applying the terminals.

Soldered Stud Terminals This style of terminal combines all the good features of both the soldered terminal and of the solid stud terminal. As shown in the illustration, two small studs, $\frac{7}{16}$ inch in diameter by a half inch long, project from the inner face of each terminal and are expanded in corresponding holes drilled into the outer side of the head or through the web of a rail. These studs in addition to making good and independent electrical contact with the steel, relieve the solder of all jarring strains which alone tend to shorten the life of a soldered bond contact. Extremely good soldered contacts are easily secured with this style of terminal, for in compressing the studs into the holes the two plane soldering surfaces are brought without the use of clamps into an intimate contact which is ideal for soldering. This double form of contact which the terminal makes with the steel is large in area, extremely efficient and as durable as the rail. It has the strength of a well made welded contact, with the added advantage of not requiring for its installation any elaborate heating equipment or any dangerously high working temperatures.



Type B. S. B., Form A Bond

In the installation of this terminal, the rail is first drilled with one of our two or four-spindle drills. The rail surface is then brightened and tinned the same as for soldered bonds. The terminal studs are then hammered home if in the head of the rail, or compressed if in the web. The rail is then reheated and the bond is soldered as described on preceding page for soldered bonds. The work if carefully done will need no testing. The cost of installation will be but little in excess of that for the regular soldered bond, as shown on page 38. This form of double application to the rail has been used extensively and we have yet to hear of the failure of a single terminal. It can be recommended very highly for all general bonding purposes.

Area of Contact Surfaces

For minimum I^2R losses in a rail joint, the contact area between each terminal and steel should theoretically bear the same ratio to the sectional area of the bond conductor that the specific resistance of the steel does to that of copper. This ratio varies with different grades of steel commonly used in track rails from 9 to 13, 12 being considered a good average working figure for modern railway steel. (See page 33.)

In practice it has been found unnecessary to use so large a contact area as this would require, for the following reasons. A good contact will take care of a fairly high current density without over-heating, because of the very excellent heat radiating and conducting properties of the steel to which the terminals are attached. The smaller the diameter of a solid stud the greater the contact pressure obtained under a given compression, and incidentally the smaller the contact resistance. On account of these conditions it is customary to provide a contact area which is about eight times greater than the sectional area of the bond conductor.

Actual Contact Areas of Stud Terminals in Holes through Rail Webs of Different Thicknesses

Table II

Diameter of Stud Terminal Inches	Area of Annular Contact, Square Inches		
	50-pound T-rail with $\frac{7}{16}$-inch Web	65-pound T-rail with ½-inch Web	84-pound to 100-pound T-rail with $\frac{9}{16}$-inch Web
½	.69	.79	.88
⅝	.86	.98	1.10
¾	1.03	1.18	1.33
⅞	1.20	1.37	1.55
1	1.38	1.57	1.77
1⅛	1.55	1.77	1.99

Required Contact Areas of Terminal Studs having Ratios of 1 to 8

Table III

Capacity of Bond Conductor	Sectional Area in Square Inches of Bond Conductor	Contact Area of Terminal Equal to Sectional Area Bond, Times 8
1/0 B. & S. gauge	.0830	.66
2/0 B. & S. gauge	.1045	.84
3/0 B. & S. gauge	.1318	1.05
4/0 B. & S. gauge	.1662	1.33
300,000 cir. mils	.2356	1.89
500,000 cir. mils	.3927	3.14

From the above, it will be observed that for general rail bond purposes, a

1/0 bond should have stud terminals ½ inch in diameter.

2/0 bond should have stud terminals ⅝ inch in diameter.

3/0 bond should have stud terminals ¾ inch in diameter.

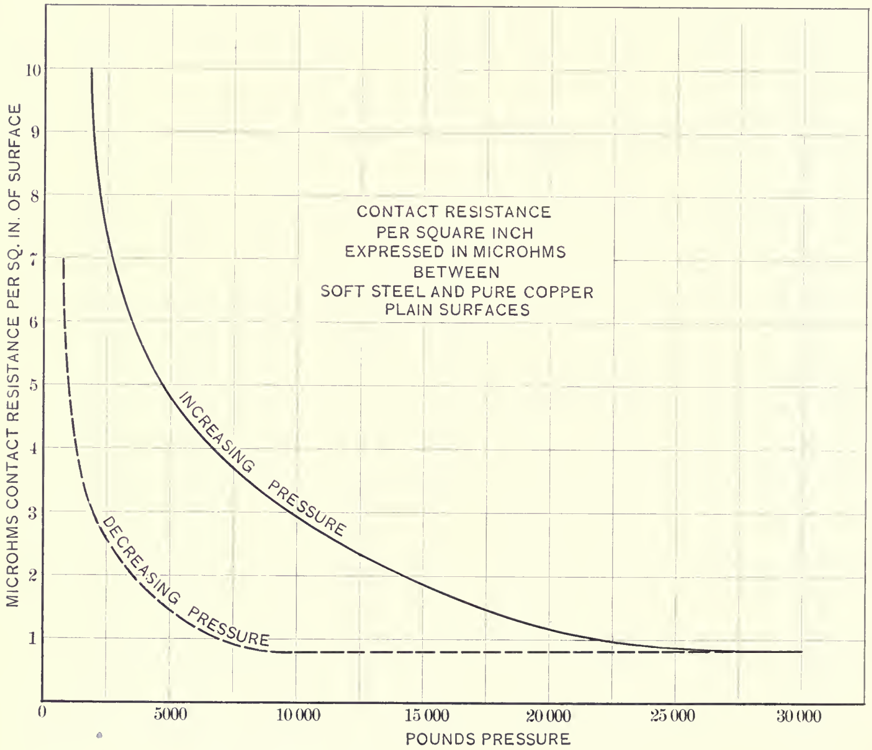
4/0 bond should have stud terminals ⅞ inch in diameter.

Larger bonds should have stud terminals from 1 inch to 1⅛ inches in diameter.

With a current density in the bond conductor of one ampere per 500 circular mils, these sizes of terminal studs will give a current density of about 320 amperes per square inch of contact surface for bond capacities of 4/0 and under. Though this current density may seem high, it has been found in practice that the suggested diameters are ample for reasons already given, and because of the general fluctuating character of the load current. This subject is continued on page 37.

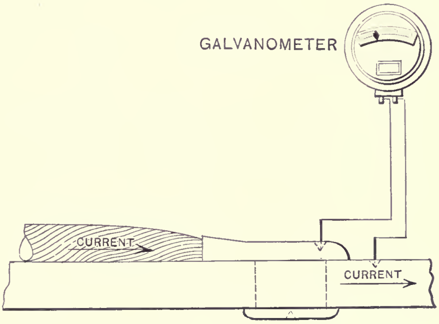
Electrical Contacts of Stud Terminals

The effectiveness of the electrical contacts between stud terminals and steel rails will depend in every case upon the physical condition of the surfaces in contact and the pressure forcing the parts together. This form of electrical contact is by far the simplest of all to make, and when properly made it is permanent and most effective.



A long and carefully conducted series of tests have been made in our rail bond laboratory to determine at different contact pressures the actual contact resistance per unit area of plane and carefully prepared surfaces of copper in contact with common railway steel. The results of these tests are given in the curves opposite. It will be observed that the contact resistance drops rapidly at first with increasing pressure until at 30,000 pounds the resistance has reached a minimum and nearly constant value of .000,000,76 ohm per square inch. If the applied pressure of 30,000 pounds be slowly reduced the contact resistance will remain constant until at 10,000 pounds, when it begins to increase, as shown in the broken line curve. In other words, only one-third of the maximum contact pressure is required to maintain the minimum contact resistance.

The actual contact resistance of a cylindrical stud terminal which has been expanded in a hole through steel cannot be measured directly with any instrument, owing to the irregular form of the contact surface. Corrections have to be made for more or less metallic resistance included. For example, suppose two galvanometer contact points be taken one-quarter inch apart in the direct path of the testing current, one point being near the edge of the crown or head of the expanded terminal and the other point in the steel itself. The testing current flowing from the bond terminal through the contact into the steel will cause a difference of potential between the two galvanometer contact points and a deflection will be produced which will be proportional to the total resistance between the two points. This resistance will consist of two parts, a portion only of the total contact resistance lying between the contact points and a certain amount of metallic resistance which must be calculated. Careful tests made in this manner with a sensitive galvanometer on cylindrical stud terminals, varying in diameter from one-half inch to one inch, show resistances varying all the way from .000,001,5 to .000,002,22 ohm per terminal, and they prove conclusively that the measured resistances are not proportional to the total contact area. Varying resistance measurements may be obtained in this manner between other sets of contact points about the same terminal showing that the actual contact resistance of the whole terminal cannot be measured by this method. But between plane surfaces it can be measured as already explained. Inasmuch as the true resistance of the copper to steel contact will depend solely on the area of contact, the pressure between and the physical condition of the two surfaces, the true contact resistance of any stud terminal can be obtained directly from the above curves for any particular pressure, other conditions remaining the same.



If, therefore, a cylindrical copper stud be placed in a hole through the web of a steel rail $\frac{9}{16}$ inch thick and having a specific resistance twelve times that of copper, and if the terminal be installed under favorable conditions, the real contact resistances would be approximately as follows:

Actual Contact Resistances of Stud Terminals under a Contact Pressure of 15 Tons per Square Inch

Table IV

Diameter of Terminal Stud, Inch	Area of Contact, Square Inches	Contact Resistance, Ohm
1	1.77	0.00000040
⅞	1.55	.00000045
¾	1.33	.00000053
⅝	1.10	.00000064
½	0.88	.00000080
2 Twin Terminal Studs	2.00	.00000035

In order to secure a contact pressure of 15 tons per square inch, a compressor should apply to the opposite faces of a solid terminal a direct pressure of at least 25 tons per square inch of terminal stud section.

The above resistance values are so extremely small that their effects may be neglected in practice. They cannot be reduced by the introduction of any known substance between the surfaces. No electrolytic action can ever take place between the metals in contact so long as moisture and air are excluded. At intermediate or lower contact pressures, the resistance will be lowered by previously amalgamating both surfaces, the amalgam under these less favorable conditions serving to increase the actual contact area, and to prolong the life of the union by excluding corroding agencies.

The presence in the joint of a thin film of clean lard oil, which is very useful in drilling steel, will increase the initial contact resistance of a well made joint less than three per cent, practically all of the oil being squeezed out of the joint. Since oil will remain unchanged so long as it is kept from heat and air, its presence about a poorly expanded terminal might even serve the useful purpose of excluding corroding agencies, thus prolonging the life of the joint.

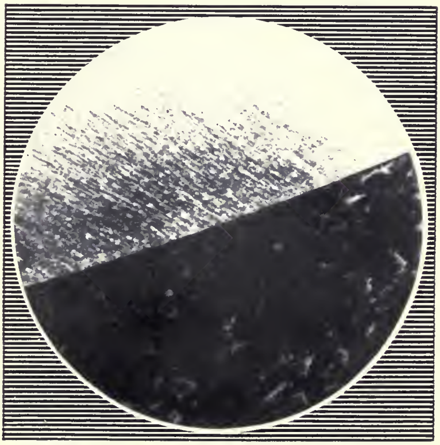
Installation To obtain in practice these extremely efficient results with stud terminal bonds, it is only necessary to observe the following few precautions while the bonds are being installed. Both contact surfaces should be smooth and they must be very clean, dry and bright at the time they are brought together. This being done, the required amount of expansion should be immediately applied to the terminals. All terminal studs are annealed and have highly polished surfaces that are exact to size within 0.005 inch when they leave our factory. Our drilling machines as described on later pages will cut holes smooth in bore and true to size, and our compressors have been built to work most effectively when correctly operated. But one thing more is needed for perfect results, and this is a very essential detail, careful and trustworthy men to do the actual work of bonding.

In one of the largest and most important electric railway systems of this country, equipped eight years ago with our stud terminal bonds, the total average depreciation of joint conductance has been under 1 per cent and not a single bond has failed without good cause. These bonds have been tested frequently and carefully and all records are preserved. There are thousands of other installations where this type of bond has served for ten or twelve years or more with little or no depreciation. Since all the bonds are essentially alike but one inference can be drawn. The secret lies in giving rigorous attention to the little details of installation. This is equally true of any type of bond. See page 61.

No management would expect that an irresponsible unskilled day laborer would make a permanent and efficient joint in an overhead feeder cable, and yet this joint is no more difficult to make nor is it of any greater importance than the bonded joint in the return track circuit which this same man is often required to make. A high resistance joint in either will cause the same load current loss and one in the track would probably cause additional trouble from electrolysis. There would be this difference, however, a poor feeder joint would very likely become apparent, while the defective joint in the track would remain unnoticed until located by means of some test.

The accompanying photomicrograph of the physical contact made between steel and a compressed copper terminal stud shows plainly the perfect union of the two metals. Not a single open space or separation can be detected in such a union at a magnification of 1600 diameters, just a fine line contact. Under the tremendous contact pressures obtained, there results an adhesion of the surfaces, an actual meshing together of adjacent particles, which ensures a perfect electrical contact, and one which will endure permanently.

Copper



Steel

Union between Steel and Compressed Copper Terminal. (150 Diameters)

Temperature Effects It is sometimes asserted that temperature changes due to varying weather conditions will cause a copper stud terminal to loosen and make poor contact, owing to copper having a higher temperature coefficient of expansion than steel. While this statement might be true of soft copper, it is not true of the extremely hard copper constituting a terminal which has been expanded.

While a terminal is being expanded, there will be a flow of the copper and a distortion of form. The copper hardens and becomes elastic to a degree depending on the amount of distortion, and it loses its malleable properties.

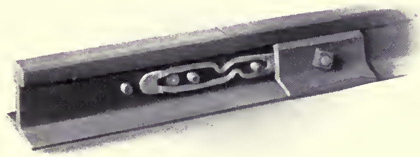
The intense lateral pressure of the expanding copper stud against the confining wall of steel will distort both metals, compressing the one and expanding the other, but both within their elastic limits. There will reside potentially and permanently in each of these metals under this stress a certain restitution pressure which is more than sufficient to maintain a nearly constant contact pressure even with the slightly unequal expansions or contractions brought into action by normal temperature changes. In other words, the elastic properties of these two metals will allow a certain give-and-take action between them which within normal temperature ranges considerably more than counteracts the effects due to differing temperature coefficients. This action maintains a nearly constant contact pressure and there is no flow or displacement of copper from the hole. Only at the higher temperatures of 230 to 400 degrees Fahrenheit and above will the greater expansion of the copper cause a flow of this metal out of the hole, the amount being proportional to the temperature elevation. But these are abnormal temperatures so far as rail bonds are concerned, and need not be further considered here.

Rail Bond Conductors

The return current is transmitted from one bond terminal to the other through some form of a copper conductor. This may vary in length, form and cross section, but it must always be more or less flexible, for all rail joints are subjected to vibrations due to the hammer blows of car wheels passing over the joints, and to occasional endwise movements of the rails caused by temperature changes. These conditions require that some form of loop or crimp be placed in all bond conductors, that solid conductors be quite long to absorb the vibrations, and that all short conductors be built up of very flexible small round stranded wires, or thin copper ribbons.

If a rail bond be placed underneath the splice bars, the conductor is usually divided into two branches, one passing above the track bolts, the other underneath. If the available space underneath the bolt is greater than that above, the lower conductor branch is often made larger than the upper branch, in which case the bond is said to be "unbalanced," to distinguish it from the so-called "balanced" bonds which have branches of equal sectional area.

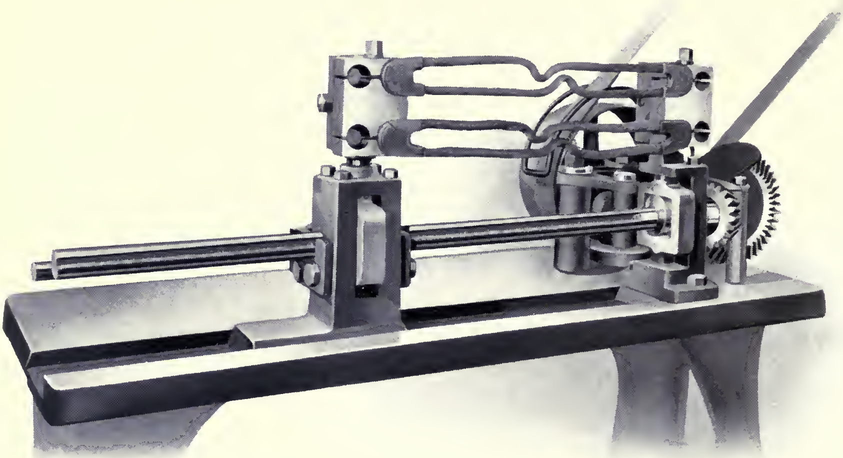
If the space between the rail web and the splice bar is narrow it is usual to build up the conductor of narrow flat ribbons laid parallel one above the other to economize in space. If this space is large enough to accommodate strands made up of very small wires, these are generally used in preference to flat ribbons because of advantages to be mentioned later. In classifying these bonds, those having unbalanced branches are given the odd form numbers 1, 3 or 5, while those with equal branches are designated with the even form numbers 2, 4 or 6. If the two loops in the branches are near the center of the bond, the bond is numbered 1 if unbalanced, or 2 if balanced; if the loops are near one end it is numbered 3 or 4, and if at opposite ends, 5 or 6, as fully explained in Part II of this book.



A short exposed bond attached to the head or to the flange of a rail usually has a single deep loop in the flexible conductor. Long exposed bonds have either a coarse wire strand or a solid wire conductor; the latter is used almost exclusively for cross bonds and for long bonds around special work. Whenever possible the loop in any bond is placed near the center of the conductor, and is made quite long and deep to absorb the motions of the joint. Sometimes it has to be placed near one end to avoid the track bolts or other objects.

Vibration Tests The continual bending of a copper wire of any section will in time harden and crystallize the copper locally and cause it to break, due to inherent properties of the metal. In order to withstand the track vibrations and jarring indefinitely, the wire in a bond conductor should be small in section, quite long and it should be annealed very soft. All wires must be entirely free from nicks or surface imperfections and they should contain but one loop. These statements though self evident can readily be verified by experiment.

The cut on next page represents a machine specially designed for making vibration tests of rail bonds. The upright clamps which rigidly grip the bond terminals are caused by cams to move rapidly in alternate and opposite vertical directions, through any desired distance. Coincident with every 125 vertical oscillations the bond is lengthened and shortened once through any required distance by the horizontal movement of the outer upright spindle, thus making it possible to approximate all the motions of a very loose rail joint.



Vibration Testing Machine

A large number of tests which have been made in this machine have developed the following facts: Wires having a diameter of from .040-inch to .045-inch twisted into a strand, give best general service for short bonds. A short straight copper wire of this size will withstand approximately twice as many vibrations as a wire of same length and twice the diameter. A single loop in the small wire will double its useful life, while in the larger wire the effect of the loop is less marked. For durability, the conductors of a two-branch concealed bond should enter straight into the shoulder of the terminal without any appreciable bend, as in the Type CP-02 bond shown on page 64. Each separate conductor wire whether round or flat should be in perfect condition at this its weakest point, and is so made in all our bonds.

Drop Hammer

The life of a bond placed on a loose joint is determined largely by its length, as will be observed from a study of the following breaking tests obtained from breaking many Type CP-02 4/0 bonds of varying lengths in the machine above described. All of the bonds were subjected to similar tests. This test represents extremely poor joint conditions, and gives no indications whatever of the life of a bond on a good joint. The wires in the 7-inch bonds began breaking at the end of 41,000 vibrations, while the

8-inch bonds began breaking at 215,000 vibrations,
10-inch bonds began breaking at 1,279,000 vibrations and the
14-inch bonds began breaking at 7,887,000 vibrations.

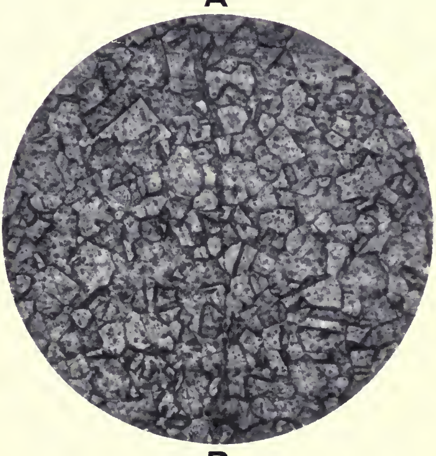
Thus the 14-inch bond withstood this particular breaking test 192 times as long as the 7-inch bond. This type of bond will remain intact under severe service conditions longer than a ribbon bond of similar style and dimensions. There is also another difference in favor of the strand of small wires when used on poor rail joints; the individual wires will seldom if ever be caught between the splice bar and rail, while ribbons of wire, not being bound together throughout their length, as in a strand, will often be caught in this manner and broken.

The Welded Union Between Terminal and Conductor

In the making of a stud terminal bond, the blank terminals of pure annealed copper are drilled or milled for the reception of the conductor portion, previously cut to proper length, and the parts are then assembled. The bond terminals are then placed in a specially constructed furnace having a closely regulated reducing flame and quickly brought to a welding temperature without causing the bond wires to be oxidized or injured in the least. The heated parts are transferred to a die and welded together by blows of a powerful drop hammer, resulting in an actual amalgamation of the parts. The union has the same high conductivity and the same physical strength as the solid pure metal. These statements may be verified by any chemical, electrical or physical test or by a microscropic examination of the union, such as shown herewith.

The accompanying photomicrograph represents a typical weld, magnified two hundred diameters. That an actual coalescence rather than an approximation of the

A



B

A Copper Weld
(200 diameters)

surfaces has taken place is made evident by noting several grains of the crystalloid structure which have grown completely across the junction line, A. B.

The successful working out of the many small details arising during the process of manufacturing a bond is learned only by years of practice, by close observation and by constant research work. These have determined to a very large extent the very complete and excellent line of bonds shown in Part II of this book.

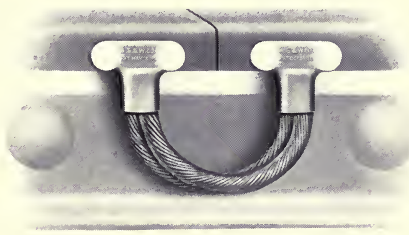
Selection of Rail Bonds

Many considerations should be taken into account when selecting a type of bond for any given track service, otherwise the bond may fail to give service through no fault in its design or construction. This article, together with the arranging and cataloging of all the bonds shown in Part II, have been prepared with a view of assisting our patrons in making the best possible selection of bonds for any given set of conditions. The first thing to be decided in making such a selection is whether they shall be

Concealed or Exposed In laying new track, bonds can be placed under splice bars at little or no additional cost, provided there is enough space for them. In this position they are protected from theft and from breakage due to external causes, but they are not open to visual inspection nor can their condition at later periods be determined except by making electrical tests of the joints. In our various types of Crown and United States bonds, pages 60 to 85, we offer an excellent choice that will meet any condition requiring concealed bonds.

If splice bars be removed from old rails, the bolts usually have to be cut, and it is seldom possible to draw the plates back into their original seat where they will make as good a joint as they did before opening. In rebonding old track it is therefore often advisable to use exposed bonds. And in new track work also, there are many conditions where this would be advisable, such as in paved streets, on private rights of way, and on joints where no other type could be used to advantage. If it be advisable to use an exposed bond, the question arises whether it shall be attached to the head of the rail, to the web bridging the splice bars, or to the flange.

Regarding the latter type (page 91) experience has demonstrated that it gives best service on feeder rails. Its application requires the removal of splice bars. Long bonds bridging splice bars in general are flexible and durable, and they can be applied easily and at small cost, but they are open to the following objections: High first cost on account of the amount of copper involved, liability of theft in many localities for a like reason, and low conductance on account of length. In general, the rails on account of their comparatively large section are more conductive than the bonds used. The use of long bonds therefore will indirectly cause an added increase in the total track resistance by cutting out of circuit a larger portion of rail.



The use of bonds applied to the head of rails during the past decade has proven very satisfactory, and in general this type of bond should be chosen whenever conditions will permit of its use, especially for open track work. This type of bond has several valuable features. It can be applied at low cost and without disturbing the joint; it is always open to visual inspection and is very high in conductance owing to the short length of conductor and large terminal contact areas. Our Twin Terminal bond (page 52) and our type B. S. B. bond (page 56), and the apparatus for applying them, have all been developed to the highest state of perfection for this class of service. Regarding the latter type especially, we challenge the world to show its equal from any consideration. These bonds are not open to the objections of theft because of the great difficulty of removing the terminals and on account of the small amount of copper exposed.

Pure copper, being malleable, is easily abraided and worn away by contact with harder substances, and copper wire, if small in diameter, is easily broken. If exposed copper bonds of any type be allowed to come in contact with pavements or wagon wheels, or other such objects, one should expect that sooner or later such bonds would be injured or entirely broken. The careful railway manager who looks after the little details will see to it that such bonds are *protected* from such destructive agencies at the time of installation, and the efficiency of his track return system will be improved and prolonged to that extent.

Having decided on the type of bond to be used in any given installation we must settle next upon the

Length of Bonds If the type to be used is a head bond or a foot bond the matter is in most cases already settled, for these bonds are regularly made in standard lengths. It should be borne in mind, however, that if they are to be used on 60-foot rails, or on very small rails subjected to heavy traffic conditions, or if they are to be used on loose joints, the bonds should be made with extra long loops of fine wire strand, otherwise the conductor might soon be broken by the excessive jarring or vibration of the joint. Long bonds for spanning splice bars on small rails should be made about five (5) inches longer (formed) than the splice bars, and about six (6) inches longer than the splice bars on large rails.

The length of a concealed bond is determined within certain limits by the bolt hole drilling. Unless the rail joint be rigidly buried in concrete paving, no short concealed bonds of any kind should be used. For general conditions the leading engineers are now specifying bonds for single bonding which are 10 inches long or more, the terminals being placed between the first and second bolt holes. In double bonding it is customary to place one terminal of each bond between the first and second bolt hole of each rail, and the other terminals beyond the second bolt holes. On electrified steam roads it is customary in this country to use concealed bonds from 16 to 24 inches long. The shocks and jarrings of the joint are gradually absorbed throughout the length of such long bonds, and the period required to crystallize and break the copper wires would be prolonged in proportion to the increased length. In cases where the conductors were rigidly clamped under the plates this condition would not of course hold true. In locating holes for concealed bonds, at least one inch of solid metal should be left in the rail web between the bolt and the terminal holes. After having fixed upon the type and the length of bond to be used, the final and most difficult feature to be settled is its

Carrying Capacity The electric generators at any railway power house produce a nearly constant potential difference of, say, 600 volts, practically all of which is required to force the load current first through the copper feeder system, then through the car motors where it overcomes counter e. m. f. and does useful work, and finally through the track return circuit. The number of volts available for doing useful work in the motors will equal the 600 generated minus the number required to overcome the combined resistance of the feeder circuit and the return circuit, which are lost so far as useful work is concerned. The only method of reducing this loss is by decreasing the resistance of the circuit. That of the feeder circuit will depend upon the length and the combined sectional area of all feeder and trolley wires in parallel and may be considered constant in this connection. The number of volts lost in forcing the load current through any portion of the track circuit will equal the product of the current times the resistance of that portion of the circuit ($E = I\ R$, see "Notes on Electricity," Part IV). One of the factors, I, the current, is fixed by the motor load, the other factor, R, alone can be varied as will be pointed out later. In interurban railway systems using medium sized rails, it is considered good practice to allow a loss in a single track of two rails from two to five volts per mile per 100 amperes of load current, depending on size of rail and other conditions. The total feeder circuit resistance is made from one to ten times that of the return track resistance, this also depending on local conditions.

The electrical resistance per mile of track will depend upon the resistance of the steel rails themselves, and of the rail joints. Let us first consider the resistance of the steel rails.

Steel Rails The resistance of common railway steel varies widely in different samples, depending largely upon the chemical composition of the metal. In general it is much higher in modern rails than in the earlier makes of rails. According to best authorities, special soft steels used for third rail purposes have resistances from 7.9 to 9 times that of copper for equal sections, while the steel in running rails varies from 11 to 13 times that of copper, or even more. The resistance ratio of manganese steel to copper sometimes exceeds 30. The copper equivalent of steel in conductance is given in the following table for various ratios:

Area of Copper in Circular Mils Equivalent to Railway Steel in Conductivity

Table V

Weight of Rail Pounds Per Yard	Actual Area in		Ratio of Resistance of Steel to that of Copper				
	Square Inches	Circular Mils	8	10	11	12	13
50	4.90	6,238,800	779,850	623,880	567,164	519,900	479,908
60	5.88	7,486,600	935,825	748,660	680,600	623,883	575,890
70	6.86	8,734,400	1,091,800	873,440	794,036	727,866	671,876
80	7.84	9,982,100	1,247,763	998,210	907,463	831,841	767,853
90	8.82	11,229,900	1,403,737	1,122,990	1,020,900	935,825	863,838
100	9.80	12,477,700	1,559,712	1,247,770	1,134,336	1,039,812	959,823
110	10.78	13,725,400	1,715,675	1,372,540	1,247,763	1,143,783	1,055,800
120	11.76	14,973,200	1,871,650	1,497,320	1,361,200	1,247,766	1,151,784

At a ratio of 1:12 the copper equivalent of steel in circular mils approximately equals its weight per yard in pounds, multiplied by 10,000.

Resistance in International Ohms of a Continuous Steel Rail at 20° C. or 68° F., no Joints

Table VI

Weight of Rail Pounds Per Yard	Ratio of Resistance of Steel to that of Copper									
	8		10		11		12		13	
	1000 Ft.	Mile	1000 Ft.	Mile	1000 Ft.	Mile	1000 Ft.	Mile	1000 Ft.	Mile
50	.013243	.069923	.016605	.087674	.018266	.096444	.019925	.105204	.021587	.113979
60	.011071	.058455	.013838	.073065	.015221	.080367	.016606	.087680	.017989	.094982
70	.009489	.050097	.011861	.062621	.013047	.068888	.014233	.075152	.015419	.081412
80	.008303	.043834	.010378	.054796	.011416	.060276	.012454	.065757	.013480	.071174
90	.007380	.038966	.009225	.048708	.010147	.053576	.011070	.058449	.011992	.063318
100	.006642	.035070	.008302	.043835	.009133	.048222	.009963	.052604	.010794	.056992
110	.006039	.031886	.007548	.039853	.008302	.043834	.009057	.047821	.009812	.051807
120	.005535	.029224	.006919	.036532	.007611	.040186	.008303	.043839	.008994	.047488

Rail Joint Resistances The resistance of a bonded rail joint measured at different times varies in accordance with the contact made by the splice bars and by the abutting ends of the rails. But since these forms of electrical contacts are transient and unreliable at best, and since their only effect would be to improve the joint conductance, their effects will, for simplicity, not be considered in the following.

The true resistance of a bonded joint is measured between points in the rail adjacent to the outer extremities of the terminals, and in line with the natural path of load current. Such measurements include the resistance of the whole bond plus both terminal contacts and a small amount of steel, and they are nearly independent of the size of the rail. As thus measured, the resistances of bonded joints at 20° C. or 68° F. are for 10-inch stud terminal bonds of various capacities, approximately as follows:

Resistance of Bonded Joints, in Ohms

(See pages 24 and 25)

Table VII

Size of Bond	Diameter of Stud Terminals in Inches	Resistance of a Joint Bonded with a 10-inch Formed Stud Terminal Bond	Total Resistance of 170 Rail Joints Bonded with 10-inch Bonds	Ohm Resistance per Inch of Duplex Parallel Bond Conductor	Total Resistance of 170 Inches of Bond Conductors
1/0	½	.00008271	.0140607	.00000792	.001346
2/0	⅝	.00006957	.0118269	.000006435	.001094
3/0	¾	.00005343	.0090831	.00000518	.000881
4/0	⅞	.00004553	.0077401	.00000410	.000697
300,000 C. M.	1	.00003443	.0058531	.00000292	.000496
500,000 C. M.	1	.00002200	.0037400	.000001782	.000309

With the above information at our command we are now in position to readily determine the approximate track resistance under nearly all conditions, and to estimate the proper carrying capacity of bonds for a given track loss. For example: What bond or bonds should be placed on a 70-pound rail that would give a track loss of four volts per mile per 100-ampere load current? Thirty-foot rails, conductivity of steel to copper, 1 : 12.

The resistance of such a track according to Ohm's law would be .04 ohm per mile, or .08 ohm for each rail. From table VI we note that the resistance of the steel itself is .07515 ohm. The difference between these two quantities or .00485 ohm represents the allowable resistance of the 170 joints in series. Looking through table VII, fourth column, we see that a single large bond or two small bonds in parallel could be used to meet the requirements. If the joints were double bonded with two small bonds, we see from page 75 that the bonds should be at least 14 inches (10 + 4) long. Referring again to table VII, the resistance of two 14-inch 4/0 bonds in parallel per 170 joints is

$$\tfrac{1}{2}\ [4\,(.000697) + .0077401] = .005264 \text{ ohm.}$$

The resistance of one mile of bonded rail would therefore be

$$.005264 + .075150 = .08041 \text{ ohm}$$

and the resistance of the track would be

$$\tfrac{1}{2}\,(.080414) = .040207 \text{ ohm,}$$

or approximately the amount required.

If it were desired to use a single bond on this joint, it will be seen from table VII that a 10-inch 500,000 circular mil bond would be too large in capacity, but that a 10-inch 300,000 circular mil bond shortened might do. This bond shortened two inches will give a total joint resistance per mile of single rail equal to (.0058531)–2(.000496) = .004861 ohm, and a track resistance per mile of .0400055 ohm. Such a large bond could not be placed under the splice bar of a 70-pound T-rail, and even if it could it would be too short for a concealed bond. Made in this capacity in the form of a twin terminal bond, or a type B. S. B., soldered stud bond and 8 inches long, the joints would be exceedingly well bonded. By decreasing the length to 7½ inches, provided the joints were in excellent shape, the loss would be further reduced.

What would be the result of using 4/0 36-inch formed bonds on these joints to bridge the splice bars? A single 4/0 bond of this length per joint would result in a total track loss of 5.1 volts per mile per 100 amperes current. Double bonding with two of these bonds would reduce the loss to 4.43 volts.

Energy Loss The following table shows the voltage drop and energy loss (I^2R) per mile of track per 100 amperes load current when each joint is bonded with a single 7½-inch 300,000 twin terminal or soldered stud bond, or with two 4/0 concealed bonds, each 14 inches long. 70-pound rails, conductivity of steel $\frac{1}{12}$ that of copper, 170 joints per mile in each rail, temperature 20° C. or 68° F.

Table VIII

Size of Rail Pounds	One 300,000 C. M.—7½-inch Bond		Two 4/0—14-inch Concealed Bonds		
	Voltage Drop in Track (2 rails) per 100 Amperes	Energy Loss in Track (I^2R) Watts per 100 Amperes	Voltage Drop in Track per 100 Amperes	Energy Loss in Track (I^2R) Watts per 100 Amperes	Per Cent of Total Loss Expended in Rail Joints
60	4.61	461	4.65	465	6.0
70	3.99	399	4.02	402	6.9
80	3.52	352	3.55	355	7.8
90	3.15	315	3.19	319	8.8
100	2.86	286	2.89	289	9.6
110	2.62	262	2.65	265	10.5
120	2.42	242	2.46	246	11.3

The four volts per mile of track which we have allowed in the above problems are utilized in forcing the 100 amperes of current through the .04 ohm of track resistance. The energy lost in doing this work equals the square of the current times the resistance (I^2R) and is expressed in watts. This energy is converted into and dissipated as heat. For example, suppose that an average of 400 amperes flows continuously for eighteen hours per day, through ten miles of the track, already considered in the above examples, what will be the loss, expressed in dollars, of electrical energy per year in the track ?

(a) Drop of volts per 100-ampere mile = 4
Track resistance per mile . 0.04 ohm and
For 10 miles . . . . . . 0.4 ohm
Loss in watts (I^2R) = $(400)^2 \times 0.4$ = 64,000 watts, or 64 K.W.
Number of hours per year = $18 \times 365 = 6570$
Number of K.W. hours per year of service = $6570 \times 64 = 420{,}480$

If the electrical energy cost 1 cent per K. W. hour delivered, the loss in the track per year as heat would equal $4,204.80, of which 7 per cent or $294.34 would represent the amount lost in the rail joints alone.

(b) If the track loss were 5.1 volts per 100-ampere mile, the energy loss, figured as above, would amount to $5,361.12 in the track.

(c) For 4.43 volts loss per 100-ampere mile, the energy loss would be $4,656.82 in the track.

These examples show clearly the advantage of using short bonds whenever conditions will permit, also the necessity of giving very careful thought to the determination of proper lengths and capacities of rail bonds, if it is desired to reduce the energy loss in the track to a minimum or stated amount. In the first example, the total resistance of 170 joints in series amounts to only .005264 ohm, or 7 per cent that of the steel resistance, a small amount. It can easily be imagined how a few poor or high resistance joints would affect our problem. A single poor joint may easily cause a loss greatly exceeding that in the rest of the mile of track, and this without being visable; hence the importance of frequent, systematic and thorough testing of bonds to discover any poor joints. (See page 39.)

According to best authorities, no dependence should ever be placed on earth or fresh water for conducting any great amount of return current. The resistance of these substances, according to best authorities, varies between wide limits, under different conditions, from 50,000,000 to 6,750,000,000 times that of copper. In general, if the bonding for any railway system has been properly figured and installed, if all special work is well bonded or shunted with good bonds, and if the bonds are maintained in first-class condition, there will be little or no leakage of current into earth, and no stray currents to cause serious electrolytic troubles.

Graduated Bonding While it is not customary in this country to graduate the bonding of railway systems, that is, to use varying sized bonds the larger ones being placed near the power house, there are quite as many reasons for doing so as for tapering the overhead feeder system. This is especially so on systems having heavy and uniformly distributed car service. A simple rule followed by some in determining the size of bonds to use on a given section of road, is to make the aggregate sectional area of all the bonds in parallel across the one or more tracks approximately equal to the sectional area of the copper feeder system above the tracks in question.

The track losses already considered vary directly as the resistance and as the square of the current. They represent too the losses at the one temperature of 20 degrees C or 68 degrees F. At higher temperatures the losses would be greater and at lower temperatures less, for the track resistance changes with temperature. They also represent conditions for direct current only. With alternating current, the impedance of the circuit is several times greater than the ohmic resistance, due to the "skin effect" of the steel rails, but the current in general would be smaller. (See page 159.)

In general, rail bonds which are large enough to keep the allowable track losses within bounds, will be more than ample to carry the load current without heating. Bare exposed conductors will carry one ampere per 500 circular mils without undue heating. At this current density, a

1/0 B. &. S gauge bond would carry 210 amperes.
2/0 B. & S. gauge bond would carry 265 amperes.
3/0 B. & S. gauge bond would carry 335 amperes.
4/0 B. & S. gauge bond would carry 425 amperes.
300,000 C. M. bond would carry 600 amperes.
500,000 C. M. bond would carry 1000 amperes.

If the bond be short, say 12 inches or less, and if the terminals be connected to rails of relatively much greater conductance, the current density could safely and without undue loss be carried 50 per cent higher than the above, because any heat developed in the bond by the load current would rapidly radiate and conduct into the large masses of steel where it would be dissipated. It is found in practice that such bonds will carry for short periods of time current densities five times as great (or 1 ampere per 100 circular mils) without injurious heating, so comparatively small bonds can be depended upon to carry very heavy momentary load currents. Extra large terminals, however, should be used on bonds frequently subjected to such heavy overloads.

Cost of Installing Rail Bonds

So many variable factors enter into the total cost of any rail bond installation that it would manifestly be impossible to give estimates that would apply accurately to individual cases. The cost would depend upon the organization of the working force, the skill and energy of the workmen, the ability of the foreman to lay out his work to best advantage, upon weather conditions, track conditions, traffic conditions and many other things. The first item is often a very important one in determining the cost of installing bonds, and for that reason we give below in tabular form information concerning the organization of gangs of men which would work under one foreman to best advantage for the installation of our various types of bonds. The number of bonds installed is based upon a full working day of eight hours, all working conditions being favorable, and no account is taken of labor which might be required to remove or replace paving or splice bars.

Type of Bond Installed (See Part II)	Bonding Tools Required	Number of Men Required in Addition to One Foreman and Their Disposition	Number of Bonds Installed per 8-hour Day
Compressed Terminal Crown and United States Bonds	Two No. 21 hand drills Two compressors, either No. 40 or No. 61	4 men on 2 drills 4 men on 2 compressors 8 men	100
	One No. 21 M motor drill Two compressors, either No. 40 or No. 61	2 men on 1 drill 4 men on 2 compressors 6 men	85
Tubular Terminal Crown and United States Bonds	Two No. 21 hand drills Supply of bonding hammers and taper punches	4 men on 2 drills 1 bonder and 1 helper 6 men	100
	One No. 21 M motor drill Supply of bonding hammers and taper punches	2 men on 1 drill 1 bonder and 1 helper 4 men	85
Type U. B. United States Bonds	One hydraulic punch No. 66 Two hydraulic compressors No. 68	2 men on punch 3 men on compressors 5 men	100
Twin Terminal Bonds	Two No. 22 hand drills Supply of bonding hammers and hand tools	4 men on 2 drills 1 bonder and 1 groove cutter 6 men	130
	Two No. 22 M or 24 M motor drills Supply of bonding hammers and hand tools	4 men on 2 drills 1 groove cutter and 2 bonders 7 men	275
Soldered Terminal Bonds	Four No. 83 torches One No. 81 electric grinder Bonding clamps, gasoline and solder	2 men for soldering 2 men for grinding 2 men for helpers 1 man for tinning 7 men	200
Type B. S. B. Soldered Stud Bonds	One No. 22 M motor drill, in addition to list required for soldering on bonds, given above	Same number of men as for soldered bonds, 2 men for motor drill, 7 men	140

This company maintains a fully equipped bonding department supervised by able and experienced engineers and manned by competent workmen, which has for many years and with marked success attended to all matters pertaining to bond installations. Through this department we are at all times prepared to install bonds, to make estimates or to advise customers regarding specifications, costs of installations and so on, or to furnish competent supervisors for installations made by the customer himself. Correspondence solicited.

Testing and Inspecting Rail Bonds

We have already called attention on a previous page to the importance of frequent and careful testing and inspection of rail bond installations. A capable man should be placed permanently in charge of this work and he should be required to make, at least twice a year, careful tests of all rail joints. He should keep permanent records of all tests, should have charge of all bonding gangs, and should be required to maintain the track circuit at a minimum resistance at all times. He should also work in conjunction with the track department and notify this department of all loose joints or other poor track construction which might lead to broken bonds.

We often hear the question asked, at what stage should a poorly bonded joint be rebonded? This will depend in every case upon how much electrical energy the company is willing to sacrifice at the joint in question when all the factors of cost and voltage fluctuation at the car have been given consideration. The resistance of any well bonded joint can be determined from table VII. If this be divided by the resistance per foot of the bonded rail given in table VI, the quotient will represent the joint resistance expressed in feet of rail. For example: If an 80-pound rail were bonded with a 12-inch 4/0 bond, what should be its resistance expressed in feet of rail, resistivity of steel 12 times that of copper?

Resistance of joint, .00004553 + 2(.0000041) = .00005373 ohm.

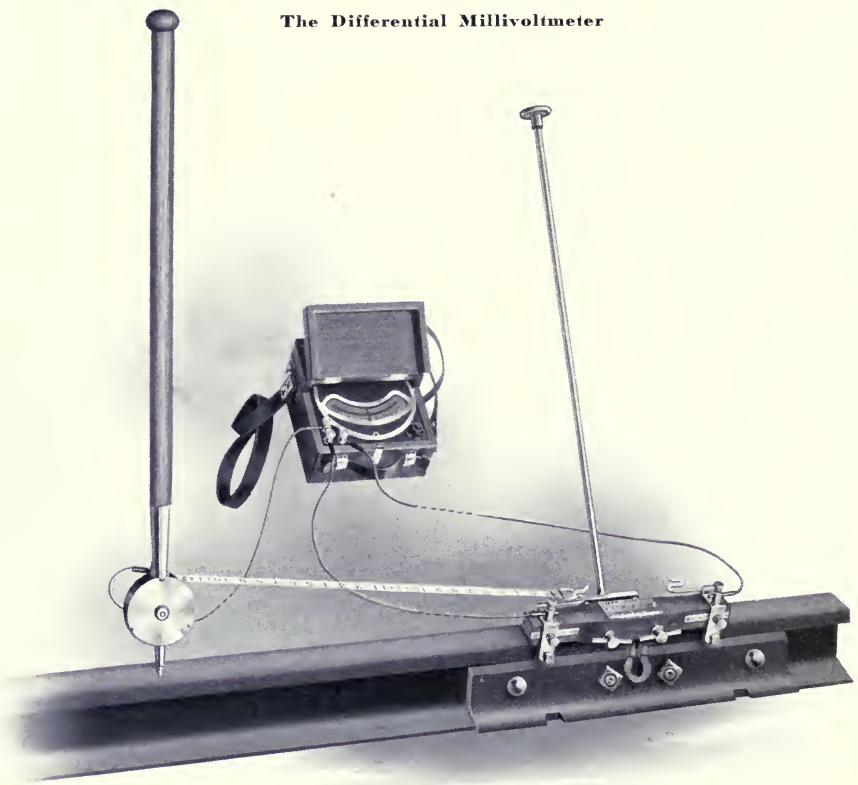
Resistance per foot of 80-pound rail, .000012454 ohm.

Feet of rail equal to resistance of joint, .00005373 ÷ .000012454 = 4.3.

From this and other examples already given it will be evident that the empirical rule advocated by some to arbitrarily classify all joints measuring 3 feet of rail as very good, and those measuring over 6 feet as bad, is absurd. The bonding may be in first class condition and still have a resistance exceeding 6 feet of rail, for the joint resistance expressed in feet of rail will depend in every case upon the length and the size of bond conductance of the rail, as well as on other conditions. To determine whether a joint should be rebonded or not, first decide the maximum voltage drop or energy loss which can be allowed in the joint, then knowing the resistance of the joint when well bonded, the maximum allowable joint resistance can readily be determined.

Rail Joint Testing The simplest way of determining the track resistance is to measure it direct by the drop of potential method, when conditions are favorable for so doing. Knowing the current flowing through a given section of track and the drop of potential across the opposite ends of the track section, the resistance will equal the quotient of the latter divided into the former. The current can be measured by an ammeter, while the drop of potential can be determined by placing a low reading voltmeter in any line, such as a pressure wire or an insulated and disconnected telephone

The Differential Millivoltmeter



Showing an A. S. & W. Bond Tester and Instrument wire that may conveniently be connected to the opposite ends of the track. The total resistance thus measured less the steel resistance will equal the aggregate joint resistance. If this latter be higher than permissible, it is customary to test each joint independently by means of some form of rail bond tester, such as those described below.

The *A. S. & W. Rail Bond Tester*, shown on opposite page, is adapted for very accurate measurements. While it can readily be operated by one man, the work can be carried on more rapidly by one man and a helper. It is a compact device for measuring the resistance of a bond in terms of the adjacent rail length. The measurements are direct reading and absolutely reliable, they are easily and rapidly obtained and accurate to within ½ inch of rail length. The only reading is taken direct from a self-winding tape line stretched along on top of the uncut rail when the differentially wound milli-voltmeter needle has been balanced, or brought to zero in the center of the scale. This is probably the most accurate and reliable bond tester ever made and should be used whenever such results are desired. See page 136 for further description of the instrument and for operating directions.

Our *Crown Bond Tester* shown on next page differs from the one described above in being self-contained and more easily handled. This instrument, however, is not intended for extremely accurate or close measurements, but for indicating rapidly and positively the general condition of bonded joints. The instrument box contains a primary battery which supplies all current required for the test, and which renders the testing set independent of any load current through the track. It has given quite satisfactory results on A. C. systems. The condition of the joint is determined by the relative intensities of two tones produced in a telephone receiver attached to the operator's ear. When the four-point contact bar is first placed on a joint, a certain definite tone will be produced which is nearly the same for all conditions, except on open joints, when no tone will be produced. By pressing the spring contact point on the rail, a different tone will in general be produced. When the intensity of this second, or switch tone, is low in comparison with the first, the bonding of a joint will be good. When the two tones are of equal intensity, the joint resistance will be equal to approximately 6 feet of 70-pound rail, or any other predetermined amount for which the instrument may be calibrated by request. The greater the comparative intensity of the switch tone, the poorer will be the bonding. With this instrument a single operator can test from 12 to 15 miles of track per day, and he will be able to discover all poorly bonded joints that may be in the track. The instrument weighs but eight pounds, is inexpensive, and contains no sensitive parts. Detailed information will be found on page 138. (Patents pending.)

Operating a Crown Bond Tester

(See preceding page)

Board of Trade Regulations for Great Britain

Regulations prescribed by the Board of Trade under the provisions of Section ______ of the ______ Tramways Act, 189__, for regulating the employment of insulated returns, or of uninsulated metallic returns of low resistance; for preventing fusion or injurious electrolytic action of or on gas or water pipes or other metallic pipes, structures or substances; and for minimizing, as far as is reasonably practicable, injurious interference with the electric wires, lines and apparatus of parties other than the company and the currents therein, whether such lines do or do not use the earth as a return.

Definitions In the following regulations: The expression "energy" means electrical energy.

The expression "generator" means the dynamo or dynamos, or other electrical apparatus used for the generation of energy.

The expression "motor" means any electric motor carried on a car and used for the conversion of energy.

The expression "pipe" means any gas or water pipe or other metallic pipe, structure or substance.

The expression "wire" means any wire apparatus used for telegraphic, telephonic electrical signaling or other similar purposes.

The expression "current" means an electric current exceeding one-thousandth part of one ampere.

The expression "of the company" has the same meaning or meanings as in the Tramways Act, 189___.

Regulations 1. Any dynamo used as a generator shall be of such pattern and construction as to be capable of producing a continuous current without appreciable pulsation.

2. One of the two conductors used for transmitting energy from the generator to the motors shall be in every case insulated from earth, and is hereinafter referred to as the "line," the other may be insulated throughout or may be insulated in such parts and to such extent as is provided in the following regulations, and is hereinafter referred to as the "returns."

3. Where any rails on which cars run, or any conductors laid between or within three feet of such rails form any part of a return, such part may be uninsulated. All other returns or parts of a return shall be insulated, unless of such sectional area as will reduce the difference of potential between the ends of the uninsulated portion of the return below the limit laid down in Regulation 7.

Board of Trade Regulations—Continued

4. When any uninsulated conductor laid between or within three feet of the rails forms any part of a return, it shall be electrically connected to the rails at distances apart not exceeding 100 feet, by means of copper strips having a sectional area of at least one-sixteenth of a square inch or by other means of equal conductivity.

5. When any part of a return is uninsulated it shall be connected with the negative terminal of the generator, and in such case the negative terminal of the generator shall also be directly connected, through the current indicator hereinafter mentioned, to two separate earth connections, which shall be placed not less than twenty yards apart.

Provided, that in place of such two earth connections, the company may make one connection to a main for water supply of not less than three inches internal diameter, with the consent of the owner thereof and of the person supplying the water; and provided that where, from the nature of the soil or for other reasons, the company can show to the satisfaction of an inspecting officer of the Board of Trade that the earth connections herein specified cannot be constructed and maintained without undue expense, the provisions of this regulation shall not apply.

The earth connections referred to in this regulation shall be constructed, laid and maintained so as to secure electrical contact with the general mass of earth, and so that an electromotive force not exceeding four volts shall suffice to produce a current of at least two amperes from one earth connection to the other through the earth, and a test shall be made at least once in every month to ascertain whether this requirement is complied with.

No portion of either earth connection shall be placed within six feet of any pipe except a main for water supply of not less than three inches internal diameter, which is metallically connected to the earth connections with the consents hereinbefore specified.

6. When the return is partly or entirely uninsulated, the company shall, in the construction and maintenance of the tramway, (a) so separate the uninsulated return from the general mass of earth and from any pipe in the vicinity; (b) so connect together the several lengths of the rails; (c) adopt such means for reducing the difference produced by the current between the potential of the uninsulated return at any one point and the potential of the uninsulated return at any other point; and (d) so maintain the efficiency of the earth connections specified in the preceding regulations as to fulfill the following conditions, viz.:

(1) That the current passing from the earth connections through the indicator to the generator shall not at any time exceed either two amperes per mile of single tramway line, or five per cent of the total current output of the station.

(2) That if at any time and at any place a test be made by connecting a galvanometer or other current indicator to the uninsulated return and to any pipe in the vicinity, it shall always be possible to reverse the direction of any current indicated by interposing a battery of three Leclanche cells connected in series if the direction of the current is from the return to the pipe, or by interposing one Leclanche cell if the direction of the current is from the pipe to the return.

In order to provide a continuous indication that the condition (1) is complied with, the company shall place in a conspicuous position a suitable, properly connected and correctly marked current indicator, and shall keep it connected during the whole time that the line is charged.

Board of Trade Regulations—Continued

The owner of any such pipe may require the company to permit him at reasonable times and intervals to ascertain by test that the conditions specified in (2) are complied with as regards his pipe.

7. When the return is partly or entirely uninsulated, a continuous record shall be kept by the company of the difference of potential during the working of the tramway between the points of the uninsulated return furthest from and nearest to the generating station. If at any time such difference of potential exceeds the limit of seven volts, the company shall take immediate steps to reduce it below that limit.

8. Every electrical connection with any pipe shall be so arranged as to admit of easy examination, and shall be tested by the company at least once in every three months.

9. Every line and every insulated return or part of a return, except any feeder, shall be constructed in sections not exceeding one-half of a mile in length, and means shall be provided for insulating each such section for purposes of testing.

10. The insulation of the line and of the return when insulated, and of all feeders and other conductors, shall be so maintained that the leakage current shall not exceed one-hundredths of an ampere per mile of tramway. The leakage current shall be ascertained daily, before or after the hours of running, when the line is fully charged. If at any time it should be found that the leakage current exceeds one-half of an ampere per mile of tramway, the leak shall be localized and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localized and removed within twenty-four hours. Provided that where both line and return are placed within a conduit, this regulation shall not apply.

11. The insulation resistance of all continuously insulated cables used for lines, for insulated returns, for feeders or for other purposes, and laid below the surface of the ground, shall not be permitted to fall below the equivalent of ten megohms for a length of one mile. A test of the insulation resistance of all such cables shall be made at least once in each month.

12. Where in any case, in any part of the tramway, the line is erected overhead and the return is laid on or under the ground, and where any wires have been erected or laid before the construction of the tramways in the same or nearly the same direction as such part of the tramway, the company shall, if required to do so by the owners of such wires or any of them, permit such owners to insert and maintain in the company's line one or more induction coils or other apparatus approved by the company for the purpose of preventing disturbance by electric induction. In any case in which the company withhold their approval of any such apparatus the owners may appeal to the Board of Trade, who may, if they think fit, dispense with such approval.

13. Any insulated return shall be placed parallel to and at a distance not exceeding three feet from the line, when the line and return are both erected overhead, or 18 inches when they are both laid underground.

14. In the disposition, connections and working of feeders, the company shall take all reasonable precautions to avoid injurious interference with any existing wires.

Board of Trade Regulations—Continued

15. The company shall so construct and maintain their systems as to secure good contact between the motors and the line and return respectively.

16. The company shall adopt the best means available to prevent the occurrence of undue sparking at the rubbing or rolling contacts in any place, and in the construction and use of their generator and motors.

17. In working the cars the current shall be varied as required by means of a rheostat containing at least twenty sections, or by some other equally efficient method of gradually varying resistance.

18. Where the line or return or both are laid in a conduit, the following conditions shall be complied with in the construction and maintenance of such conduit:

(a) The conduit shall be so constructed as to admit of easy examination of and access to the conductors contained therein, and their insulators and supports.

(b) It shall be so constructed as to be readily cleared of accumulation of dust or other debris, and no such accumulation shall be permitted to remain.

(c) It shall be laid to such falls and so connected to sumps or other means of drainage as to automatically clear itself of water without danger of the water reaching the level of the conductors.

(d) If the conduit is formed of metal, all separate lengths shall be so jointed as to secure efficient metallic continuity for the passage of electric currents. Where the rails are used to form any part of the return they shall be electrically connected to the conduit by means of copper strips having a sectional area of at least one-sixteenth of a square inch, or other means of equal conductivity, at distances apart not exceeding 100 feet. Where the return is wholly insulated and contained within the conduit, the latter shall be connected to earth at the generating station through a high resistance galvanometer, suitable for the indication of any or partial contact of either the line or the return with the conduit.

(e) If the conduit is formed of any non-metallic material not being of high insulating quality and impervious to moisture throughout, and is placed within six feet of any pipe, a non-conducting screen shall be interposed between the conduit and the pipe of such material and dimensions as shall provide that no current can pass between them without traversing at least six feet of earth, or the conduit itself shall in such case be lined with bitumen or other non-conducting damp-resisting material in all cases where it is placed within six feet of any pipe.

(f) The leakage current shall be ascertained daily before or after the hours of running, when the line is fully charged, and if at any time it shall be found to exceed half an ampere per mile of tramway, the leak shall be localized and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localized and removed within twenty-four hours.

19. The company shall, so far as may be applicable to their system of working, keep records, as specified below. These records shall, if and when required, be forwarded for the information of the Board of Trade.

Board of Trade Regulations—Continued

Daily Records Number of cars running; maximum working current; maximum working pressure.

Maximum current from earth connections (vide Regulation 6 (1).

Leakage current (vide Regulation 10 and 18 f).

Fall of potential in return (vide Regulation 7).

Monthly Records Condition of earth connections (vide Regulation 5).

Insulation resistance of insulated cables (vide Regulation 11).

Quarterly Records Conductance of joints to pipes (vide Regulation 8).

Occasional Records Any tests made under provisions of Regulation 6 (2).

Localization and removal of leakage, stating time occupied.

Particulars of any abnormal occurrence affecting the electric working of the tramway.

Signed by order of the Board of Trade this____________day of 19

Assistant Secretary, Board of Trade.

Typical Specifications for Rail Bonds

General The intentions of these specifications are to state the type, form, capacity and dimensions of rail bonds required, and the manner in which they are to be made, tested, packed and delivered. The completed bonds and the copper of which they are made shall conform to the requirements of the following specifications:

Description The number of bonds required is ———.
The kind of bond required is Type ——, as shown on page 000 of the (19—) Rail Bond catalogue published by ———————— Co.

All parts of these bonds shall be made of commercially pure and uniformly soft annealed copper having a conductivity of not less than 98 per cent. Matthiesen's Standard.

No individual wire shall be reduced in section or materially weakened at any point.

All terminals and all wires, whether round or flat, shall be of uniform size and quality, free from cracks, burrs, fins, slivers and hard spots.

The cylindrical surfaces of all terminal studs shall be machined smooth and true to size, and the bonds shall afterwards be carefully annealed.

All flexible stranded or laminated conductors shall be united to the terminals in such manner as to make a perfect electrical and physical union.

Dimensions All bonds furnished under these specifications shall have an aggregate cross sectional area, measured at right angles to the axes of the individual wires, of —— circular mils, or —— B. & S. gauge.

The bonds shall conform in design and dimension to the accompanying drawings which are made a part of these specifications.

The flexible conductor shall have 000 round (or flat) wires arranged and dimensioned as specified in the attached drawing.

No diameter of the terminal studs shall exceed that specified on the drawings. A variation of .005 inch will be allowed under the maximum required diameter.

Tests (a) In bonds with copper terminal heads united to conductors of either stranded cable or ribbon, the character of the union between conductor and terminal head shall be determined preferably by an electrical test, or in the following manner.

The stud of the bond shall be sawed lengthwise into four (4) equal segments, allowing the saw to cut to, but not into, the conductor. These segments shall then be bent back, tending to separate the welded parts. If a clean, bright fracture is exhibited with a surface entirely free from oxide, the weld shall be considered satisfactory.

(b) The test for *flexibility* hereinafter described is not made a condition of acceptance, but may be at the option of the company and accorded due weight in the determination of the relative excellence of the bond submitted. This test shall be made by holding rigidly one terminal of a bond while the other end is given a longitudinal movement of three-sixteenths ($\frac{3}{16}$) of an inch, or a transverse movement of three-sixteenths ($\frac{3}{16}$) of an inch, and continuing the movement until the first ribbon or wire breaks.

Packing The bonds shall be so packed for shipment that they will be suitably protected from deformation or injury, each package being plainly marked with the number, type and length of bonds, and the number of the order upon which shipment was made.

Delivery The proposition must state the shortest time after the receipt of the order in which shipment can be made.

Part II

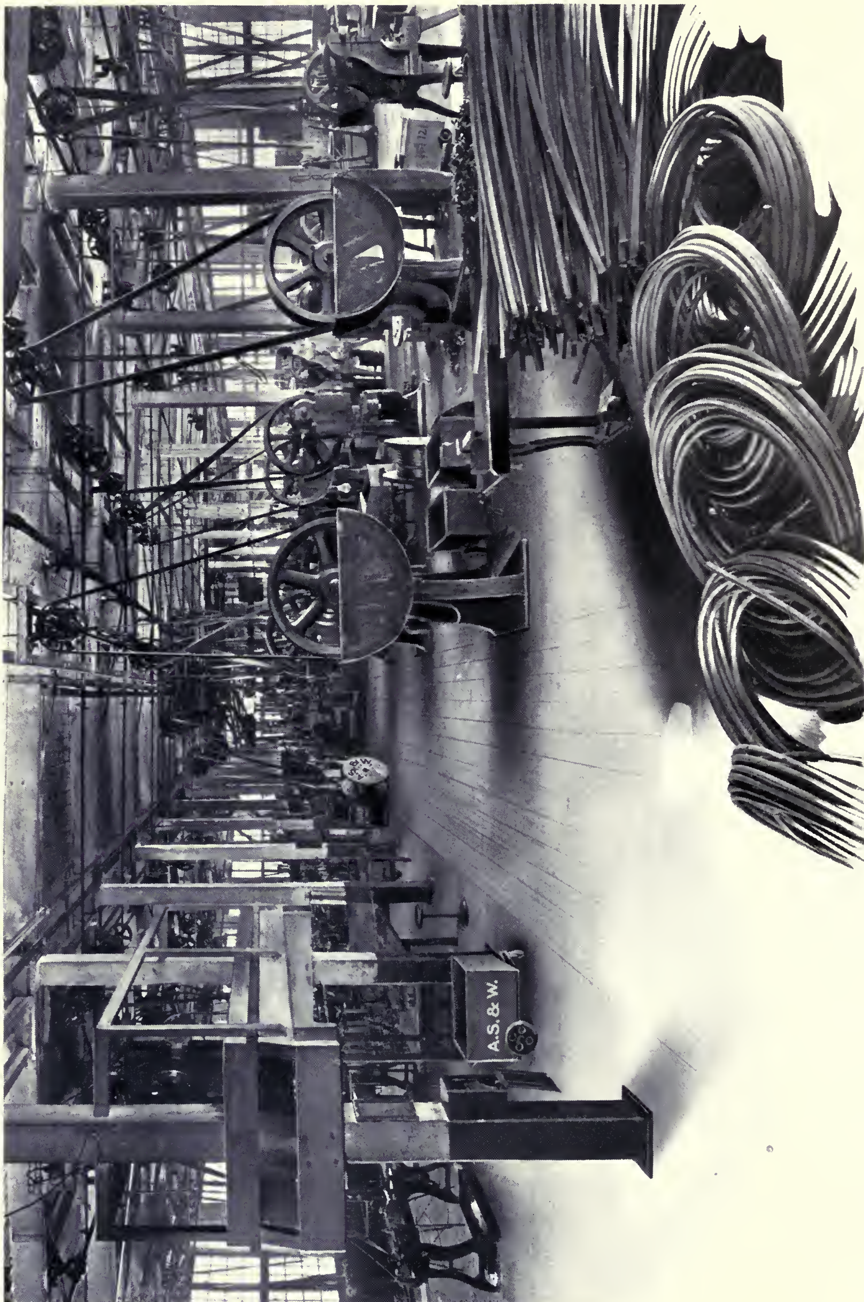
Rail Bonds

Our company makes bonds which are most carefully constructed, well finished and very high in conductivity.

The entire energies and resources of a corps of experts are devoted to the production of our rail bonds and bonding appliances, resulting in a varied product which represents the highest attainable types of excellence.

Our manufacturing facilities, which have in the past often been taxed to their utmost, have been largely increased by the addition of new buildings, fully equipped with the most modern machinery. These increased facilities will enable us to handle large orders with dispatch and to maintain the lowest possible prices consistent with the high standard of materials now required. Special attention is given to the manufacture of rail bonds to the customer's own specifications.

Inquires are solicited, and prices will be quoted upon application.



The Rail Bond Factory

Rail Bonds for Rail Heads

Twin Terminal bonds.
Soldered Stud bonds.
Solderod bonds.

For the convenience of our customers in selecting bonds best suited to their needs, the various styles and forms of bonds shown will be arranged in three groups, according as they are designed for the head, the web or the flange of rails. This, we believe, will be more convenient to the customer than any classification we might give based on construction details of the bonds, such as already made on page 13.

In the first group will be shown those bonds designed especially for application to the outer sides of heads of rails. We make three styles suitable for this purpose, given above. These differ only in style of terminals used. In general these bonds have short conductors made of fine wire strand bent into single deep loops which render them very flexible. They can be attached to any style of rail having a head thick enough for the application of the terminal.

These bonds in comparison with other types have the following distinct advantages: They can be installed without disturbing the rail joint, a feature of marked advantage in rebonding old tracks. Their cost of installation is in general less than that of other types. They are always open to visual inspection. The large terminal contact area and the short length of conductor combine to make a bond extremely high in conductivity. The twin terminal and the soldered stud bonds, owing to the extreme difficulty of removing the terminals from the rails, effectively resist theft.

All rail joints on which these bonds are used should be kept in first class condition, for no short bond can be made to last long on joints having loose plates. When these bonds are used in paved streets, the conductor wires should be mechanically protected against abrasion from the paving.

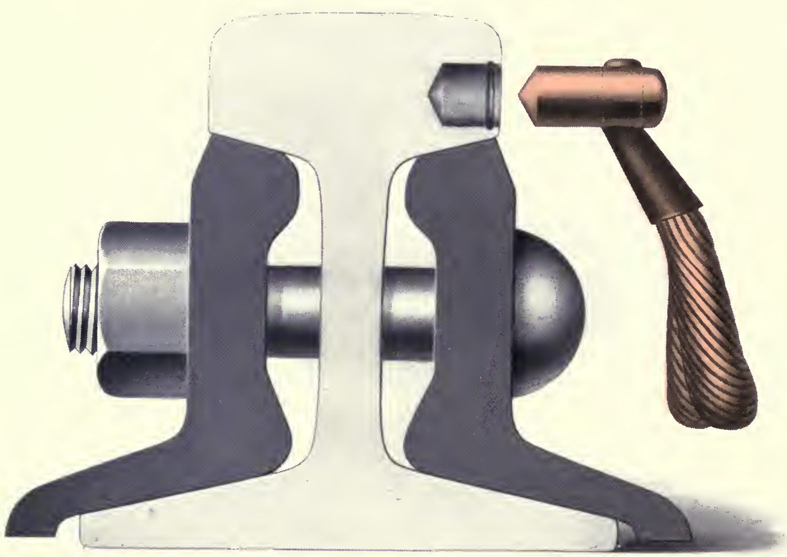
Twin Terminal Rail Bonds

Rail Bonds for Rail Heads

Twin Terminal Rail Bonds

These bonds are designed for attachment to the head of rails. They are extensively used in all parts of the United States, and they make an ideal bond for interurban railroads especially. The conductor loop extends down over the splice bar between the inner track bolts, and the four terminal studs are expanded into holes drilled in the lower edge of the outer vertical surface of rail heads as already explained on page 18. This bond can be applied to any form of rail having a head provided with an outer vertical plane surface equal to or exceeding $\frac{19}{32}$ inch in thickness. It is made in capacities up to and including 500,000 circular mils. By double bonding as shown on preceding page, any rail can easily be bonded to its full capacity.

Each terminal of this bond is provided with two parallel cylindrical studs, each of which is ½ inch in diameter by $\frac{9}{16}$ inch long for sizes of bonds up to and including 250,000 circular mils capacity or $\frac{11}{16}$ inch long for larger sizes. The studs are milled smooth and have blunt conical ends which fit into the bottom of correspondingly drilled cup-shaped holes. The two studs of each terminal are spaced 1¼ inches between centers. The outer face of the terminal is provided with copper bosses in alignment with the studs as illustrated. Each complete terminal is forged into shape from a single piece of soft rolled copper. As with our other bonds the same improved process of copper forging insures a perfect union between conductor and terminals.



Showing Terminal Stud about to be installed in Bottomed Hole

Rail Bonds for Rail Heads

Application Our four-spindle drills, described on pages 95 to 105, operated by hand or motor power, provide accurate and ready means for drilling in one operation the four ½-inch holes required for this type of bond. The outer sharp edges of the holes are rounded over slightly with a blunt expanding tool (No. 11, page 143) to avoid scarfing the close fitting terminal studs. A few threads or a single small annular groove is cut in the wall of each hole near its orifice with one of the two forms of special hand groove cutting tools shown on page 142. After this the terminal studs are inserted in the holes and then expanded with hammer blows applied squarely to the face of the terminal. At first the hammer blows should be moderate, and increased in force as the copper begins to flow over the surface of the rail. They are continued until the outer boss has disappeared and the rivet head formed is quite thin. When used in paved streets the upper edge of the terminals can easily be drawn to a thin edge that will turn off wagon wheels.

Before inserting the terminal studs into the holes, both copper and steel contact surfaces are made bright and smooth and dry and clean. The length of the copper stud is greater than the depth of the hole by $\frac{1}{16}$ of an inch or more. Hence, with the bottom of the hole serving as an anvil, the hammer blows applied to the studs force more and more copper into the holes, driving the soft material into every pore of the steel under an intense pressure which entirely fills the hole to the permanent exclusion of all corroding agencies. The copper also fills the annular grooves or threads about each hole, thoroughly sealing the hole and anchoring the studs in the hole. This annular ring formed about each stud must be entirely sheared off before the studs can even be loosened in the hole, making it difficult to remove the terminals.

Advantages Twin terminal rail bonds possess many distinct advantages of their own. The very great contact pressure obtained especially in the groove and the adjacent zone seals the hole permanently and makes an electrical contact of very high efficiency. Each single terminal stud has a contact area of one square inch or more, depending on its length. This large contact area, not easily obtained with any other type of terminal stud bond, permits the construction of very efficient and compact bonds of large capacity. No torsional stresses can ever loosen these terminals. As each stud connection to the rail is quite independent of the other, this double and independent method of attachment of terminal offers all the advantages of double bonding. The rail joint does not have to be disturbed for applying this bond, and its cost of installation is very low compared with that of any other type. The conductor is not injured by the vertical movements of the joint, for it enters the lower edge of the terminals in a direction parallel to the direction of motion.

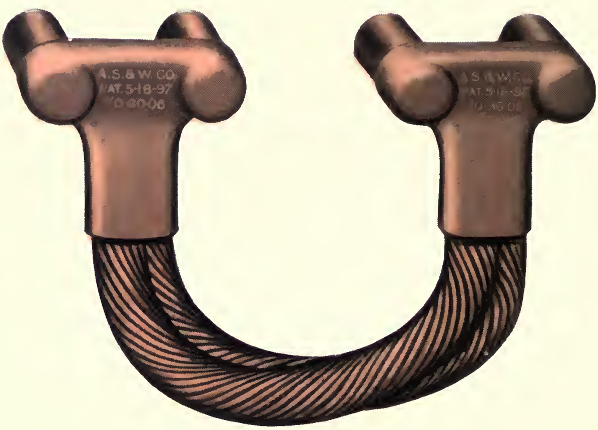
Rail Bonds for Rail Heads

Twin Terminal Rail Bonds—Continued

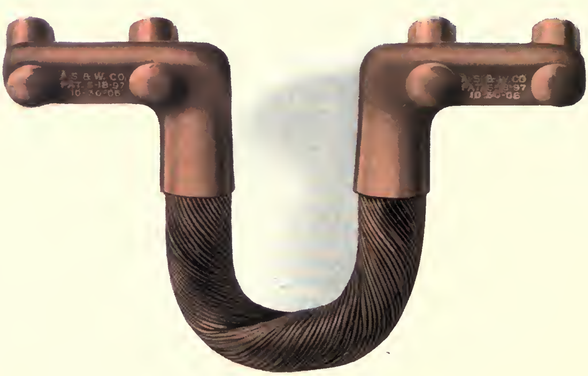
Four forms of twin terminal bonds are shown herein, differing principally in form of loop and conductor.

Form A bond, having the broad loop, is used on all joints where the two inner track bolts are far enough apart not to interfere with the bond loop. If the two inner bolts are very close together, and if neither of them can be turned so as to bring the nuts on the inside of the rail, then form B bond is recommended. Form A, B and C bonds are furnished with very small wires stranded together, making an extremely flexible and durable bond.

The extended length of standard bonds, measured from center to center of terminals between studs, is seven inches. A large quantity of these bonds always kept in stock. Other lengths to order.



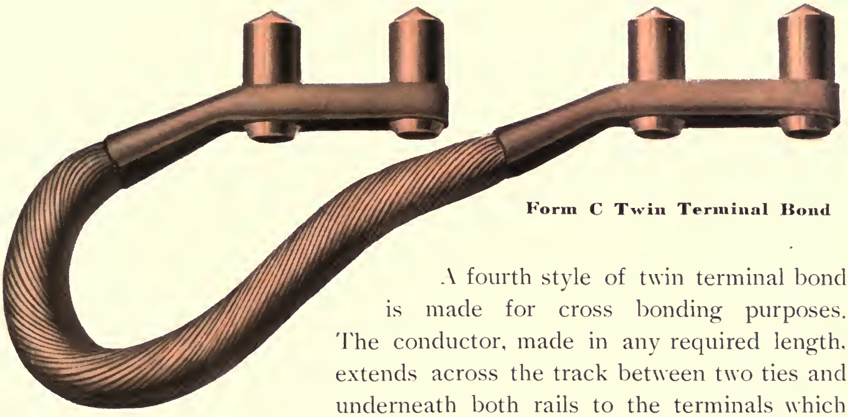
Form A Twin Terminal Bond



Form B Twin Terminal Bond

Rail Bonds for Rail Heads

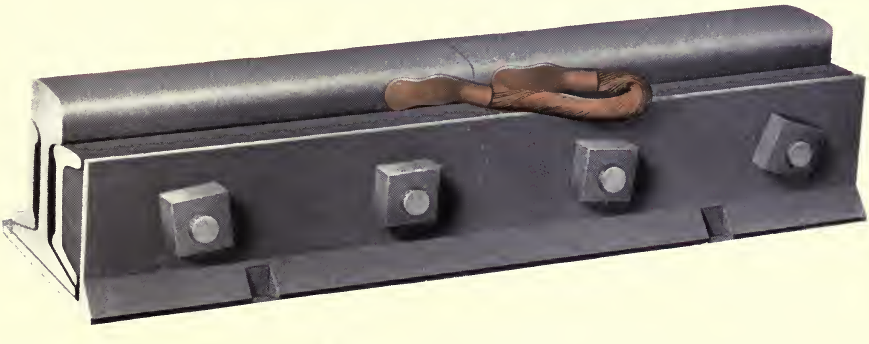
Form C Twin Terminal bond, as shown below, is made specially for application to the Weber joint. In applying this bond the inner terminal is installed first with the aid of a special punch (No. 17, page 144) resting against the terminal studs. The other terminal is then bent back into position forming the horizontal loop which lies on top of the angle bar. The four holes are drilled by either of our standard four-spindle drills described on pages 95 to 105. The extended length of these bonds measured between centers of terminals is 9½ inches.



Form C Twin Terminal Bond

A fourth style of twin terminal bond is made for cross bonding purposes. The conductor, made in any required length, extends across the track between two ties and underneath both rails to the terminals which are connected to the outer sides of the rail heads.

Twin Terminal Cross Bond



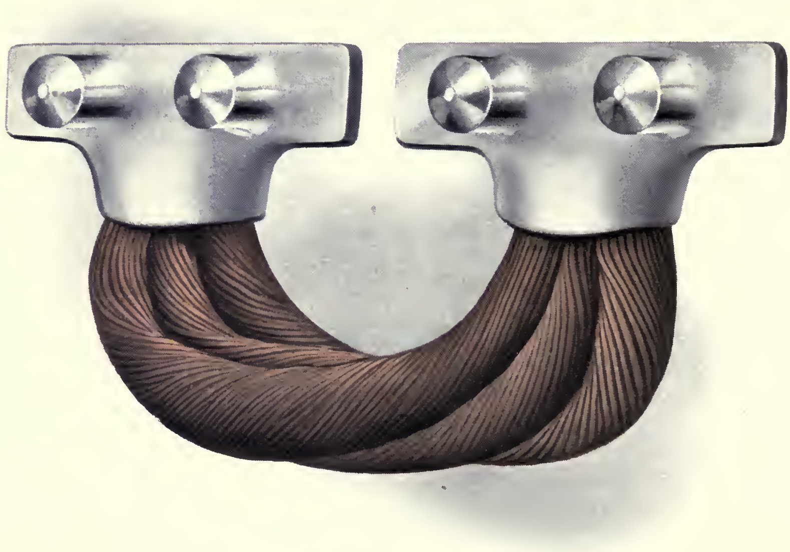
Form C Twin Terminal Bond Applied to a Weber Joint

Rail Bonds for Rail Heads

Soldered Stud Rail Bonds

This style of bond, as already explained, has a combination twin stud and soldered terminal. The terminal, as will be seen from the illustrations, differs from the standard twin terminal in being extended a half inch or so beyond each stud, so as to offer a large flat surface for soldering to the rail. It differs from the regular soldered terminal in having two small $\frac{7}{16}$-inch studs integral with the terminal and projecting from its inner surface. These studs are expanded into corresponding shallow holes drilled into the head of the rail, thus relieving the solder of all vibratory strains and greatly increasing the contact area and life of the joint.

This type of bond is made in two forms for the head of rails, similar to the twin terminal bond, and in sizes up to and including 500,000 circular mils. Form A has the broad, deep loop and is used on rail joints having plenty of space for the loop between the inner track bolts. Form B has the narrow loop for use on joints where the inner track bolts are close together. Length of bond from center to center of terminals between studs, 7½ inches extended. The bond shown below is specially suited for third rail work.

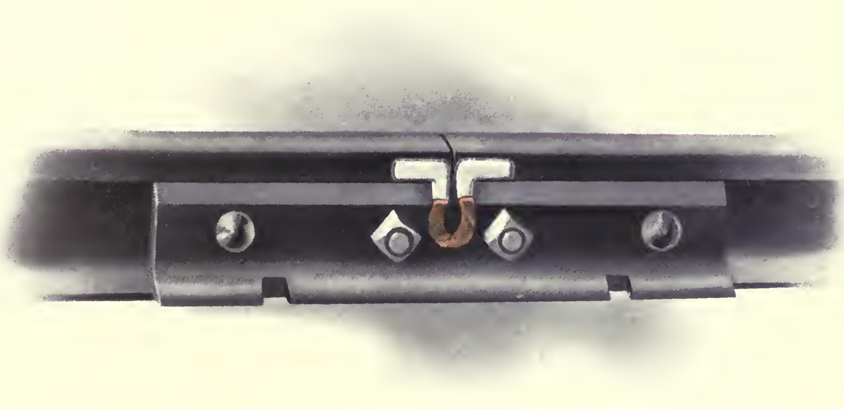


Type B. S. B. (B-est S-oldered B-ond)-Form A Bond
(500,000 circular mils capacity)

Rail Bonds for Rail Heads

Extremely good soldered contacts are easily secured with this style of terminal, for in hammering and expanding the studs into the holes, the two plane soldered surfaces are brought without the use of clamps into an intimate contact that is ideal for soldering. This double form of contact, which the terminal makes with the steel, is large in area, extremely efficient and as durable as the rail. It has the strength of a welded contact, with the added advantage of requiring no elaborate equipment and no dangerously high working temperatures for its installation. It would be impossible to imagine a more lasting or efficient form of electrical contact than can readily be obtained with this style of bond.

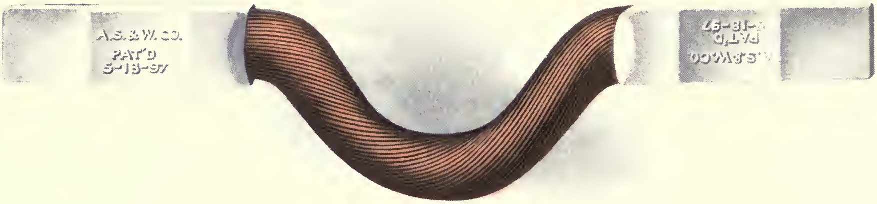
In the installation of this terminal, the rail is first drilled with one of our standard two or four-spindle drills. The rail surface is then brightened, heated and tinned the same as for soldered bonds. The terminal studs are then hammered home. The rail is then reheated and the bond is soldered, as described on page 19 for soldered bonds. The work if carefully done will need no testing. The cost of installation will be but little in excess of that for the regular soldered bond. This form of double application to the rail has been used extensively, and we have yet to learn of the failure of a single terminal. The bond is recommended very highly for any set of conditions where exposed bonds can be used. For concealed bonds of this types see pages 67 to 84.



Type B. S. B.-Form B Bond Applied to a Rail

Rail Bonds for Rail Heads

Soldered Rail Bonds

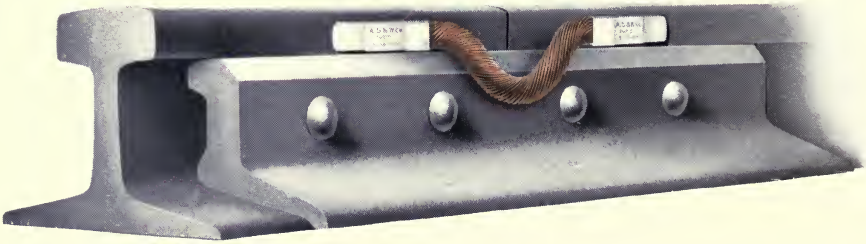


Type S. B. - Form 1 Soldered Bond

The Type S. B. (S-oldered B-ond) Form 1 Bond, shown above, has been designed for application to the head of T-rails. In this bond the flexible conductor is composed of a large number of small copper wires, twisted together into a compact strand, which is flexible in all directions. The small, tough wires do not break in the loop, and projecting or loose joint plates will not force the bond from the rail. All 3/0 and 4/0 bonds are made in two sizes each, as shown below. Those having small terminals can be used on any ordinary size of rail; large terminals used only on 70-pound standard T-rails or larger. The extended length of these bonds is measured from end to end of terminals.

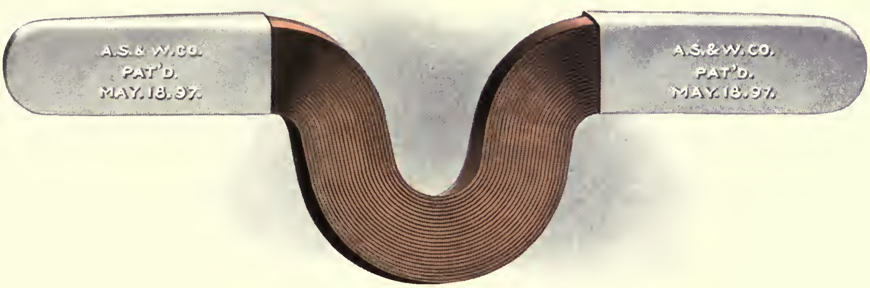
Type S. B. - Form 1 Bond

Size of Bond	Length of Bond Formed, in Inches	Dimensions of Contact Surfaces Inches	Length of Bond Extended, in Inches	Number of Wires in Conductors
1/0 B. & S.	7¼	9/16 x 2	8¼	37
2/0 B. & S.	7¼	9/16 x 2	8¼	61
3/0 B. & S.	8	5/8 x 2¼	9	91
3/0 B. & S.	8¾	3/4 x 2⅝	9¾	91
4/0 B. & S.	8	5/8 x 2¼	9	127
4/0 B. & S.	8¾	3/4 x 2⅝	9¾	127
300,000 C. M.	9	3/4 x 2⅝	10	127



Showing Application of Type S. B. - Form 1 Soldered Bond

Rail Bonds for Rail Heads



Type S. B.-Form 1 B. Soldered Bond

The bond shown above is similar to the Form 1 bond shown opposite, except that the conductor is composed of very thin copper strips instead of round wire strand. It will be observed that the depth and form of loop which is offset to clear the joint plate, insure great flexibility.

See page 19 for a general discussion of soldered contacts, and for proper methods of installing soldered bonds. For concealed soldered bonds see pages 67 to 84, and for the soldered foot bond, see page 91.

Type S. B.-Form 1 B. Bond

Size of Bond	Length of Bond Formed, in Inches	Length of Bond Extended, in Inches	Number of Copper Ribbons in Conductor
2/0 B. & S.	6½	7¾	21
3/0 B. & S.	8	9½	26
4/0 B. & S.	7¼	8¾	33
300,000 C. M.	8	9½	32
500,000 C. M.	8¼	10½	40

For a description of tools for soldered bonds, see pages 131 to 135.

Rail Bonds for Rail Webs

As already explained on page 26, rail bonds which are placed underneath the splice bars and attached to the webs of rails are usually provided with two conductor branches, each of which is made either of stranded fine copper wires (Crown bonds) or of thin copper strips laid parallel (United States bonds). The former style of bond is generally used in all cases where the space underneath the splice bar is large enough not to compress the strand, while the latter style is used in all joints having narrow spaces between plate and web. There is a third class of single strand Crown bonds made to extend around the splice bars, and for cross bonding and special purposes. These three styles of bonds are made in different capacities, lengths and forms to meet the great variety of track conditions, as will be pointed out in the following pages. The lengths of these bonds are measured between centers of terminals. The principal advantage of placing bonds under splice bars, is protection against theft and from external mechanical injury. For application between a splice bar and the web of a rail, a bond of such type and size should be selected, as will never be compressed or injured by the bar. The bond conductors should also be carefully formed or bent into shape after installation.

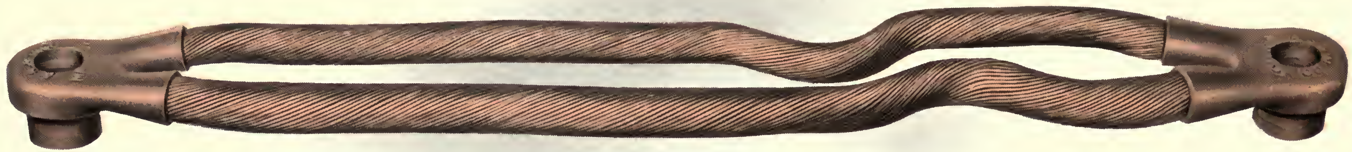
Many of the forms of bond conductors, as will be seen, can be provided with any one of the following styles of terminals:

(a) Single solid stud terminals for compression.
(b) Single tubular stud terminals for pin expansion.
(c) Double stud terminals for compression.
(d) Double stud soldered terminals for compression and soldering.
(e) Soldered terminals for soldering to the webs.

Style (d) terminal differs from style (c) only in having its surfaces tinned ready for soldering to the rail surface. The relative merits of these various kinds of terminals have already been fully discussed on pages 15 to 20, to which the reader is referred.

In the following pages will be shown the various styles and forms of Crown and United States bonds, having duplex parallel branches. Each will be divided into two general classes. First will be shown those in which the branches enter the terminal head in a straight line, or are tangent to the terminal studs. The merits of this style have already been pointed out on page 28. Secondly, those bonds in which the branches converge at and enter the central portion of the terminal heads. A single rail bond of each form of this series will be shown in two views at the top of a page. On the same page below will be shown one end only of the other bonds in the same series.

Concealed Rail Bonds for Rail Webs



Crown Bond, Type C. P.-01

We believe that no one style of bond ever made has been required to serve more important functions or to meet more severe service conditions than that shown above. For this reason we are giving it this special prominence. It was selected by the respective engineers in preference to all other types, and is being used as the track bond on the electrified portions of:

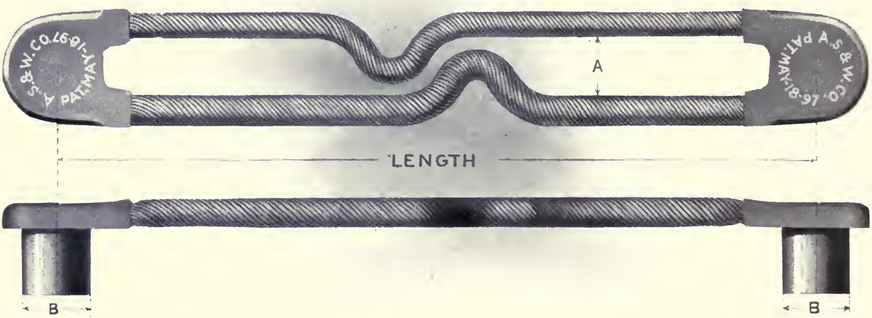
The New York Central and Hudson River Railroad
New York, New Haven and Hartford Railroad
Pennsylvania Railroad, and the
Southern Pacific Railroad

It can be installed cheaply and effectively, and without the aid of cumbersome tools, by unskilled labor working under competent supervision. It is distinguished for its great flexibility and durability, for its high conductivity and for the superior workmanship put into its construction.

The bond has been sold in large numbers not only in this country, but in all parts of the world. It has been in service for many years, and its endurance under most severe conditions is most gratifying.

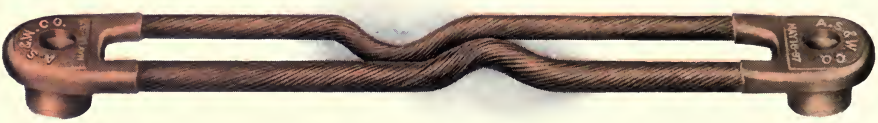
Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)

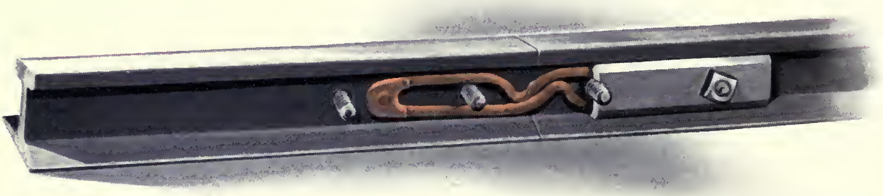


Type C. S.-01 Crown Bond

These bonds are used largely for single bonding on rail joints having a larger bonding space below than above the track bolts. The terminals are usually placed midway between the first and second bolts. Made in any length or capacity.



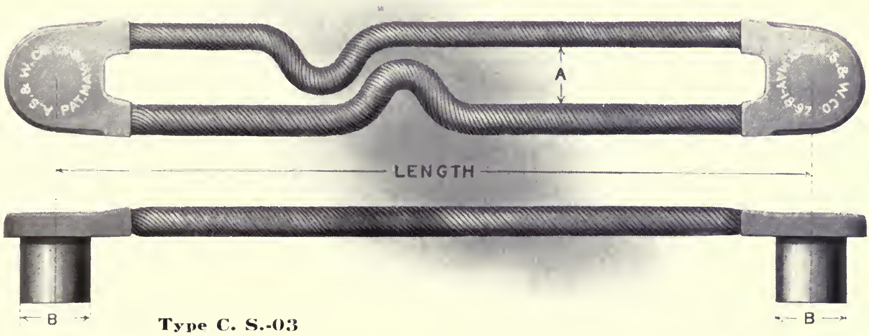
Type C. P.-01 Crown Bond



Showing a Type C. P.-01 Crown Bond Installed on a Rail

Concealed Rail Bonds for Rail Webs

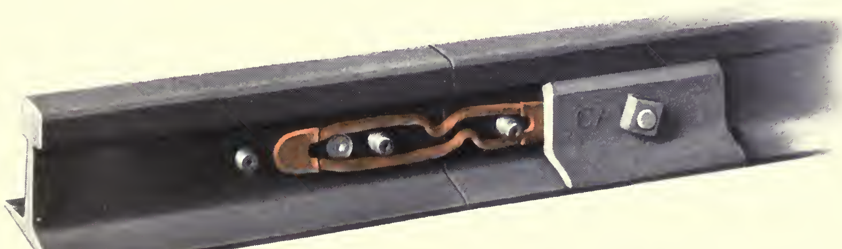
(See pages 60 and 74)



Type C. S.-03
Crown Bond

The bonds shown here are used largely for double bonding on rail joints having a larger bonding space below than above the track bolts. One terminal is usually placed between the first and second bolt holes of one rail and the other is placed between the second and third bolt holes of the other rail, the two bonds being staggered. The long open space between the conductors at one end of the bond provides room for one track bolt and one terminal of the opposite bond, as shown below. Made in any length or capacity.

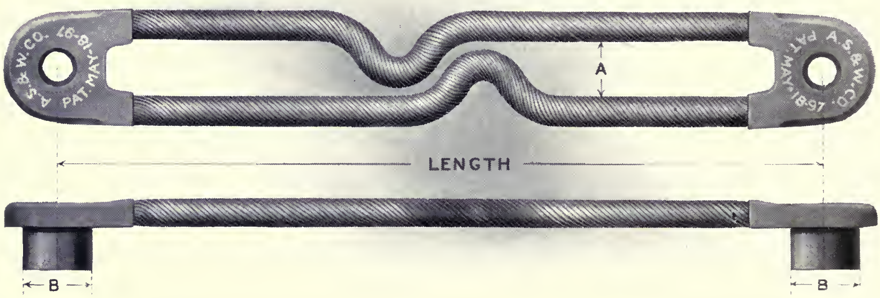
Type C. P.-03 Crown Bond



Showing a Type C. S.-03 Crown Bond Installed on a Rail

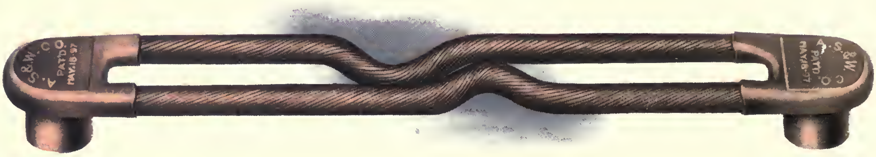
Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)

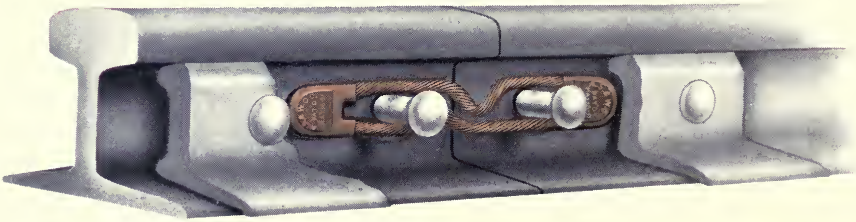


Type C. P.-02 Crown Bond

These bonds are used largely for single bonding on rail joints having equal bonding spaces above and below the track bolts. The terminals are usually placed midway between the first and second bolt holes. Made in any length or capacity.



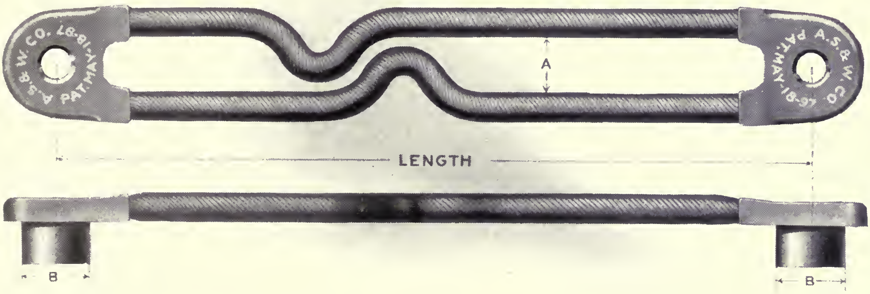
Type C. S.-02 Crown Bond



Showing a Type C. S.-02 Crown Bond Installed on a Rail

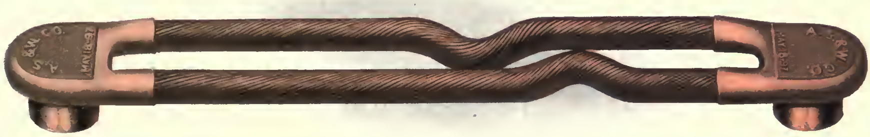
Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)

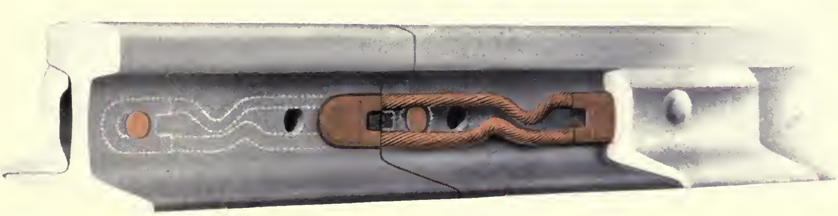


Type C. P.-04 Crown Bond

The bonds shown here are used for double bonding on rail joints having equal bonding spaces above and below the track bolts. One terminal is usually placed midway between the first and second bolt holes of one rail and the other terminal is placed between the second and third holes of the other rail, the two bonds being staggered. The long open space between the conductors at one end of the bond provides ample room for one bolt and one terminal of the bond on the other side of the rail. Made in any length or capacity required.



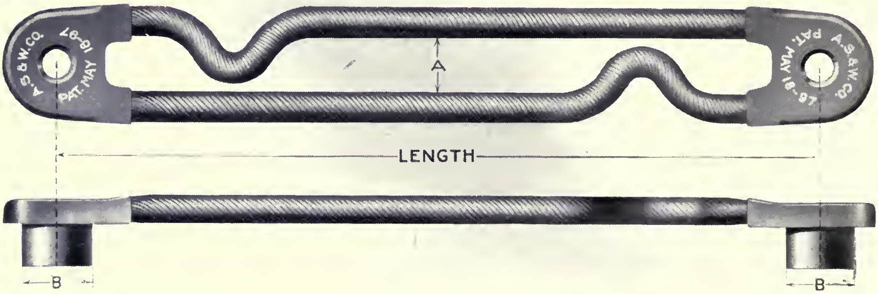
Type C. S.-04 Crown Bond



Showing a Type C. S.-04 Bond Attached to the Web of a Rail

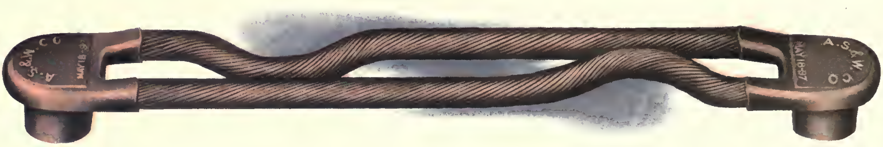
Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)



Type C. P.-06 Crown Bond

This form of bond is used for single bonding or for double bonding. Except in very special cases, this style of forming the conductor loops is not as satisfactory as those shown on the two preceding pages, and on this account none of the other styles of Crown bonds will be shown with this form of loop, but any of them may be so formed upon request. Bonds with unequal sized branches will take form No. 5, while those with equal branches will take the form No. 6. Made in any size or length.

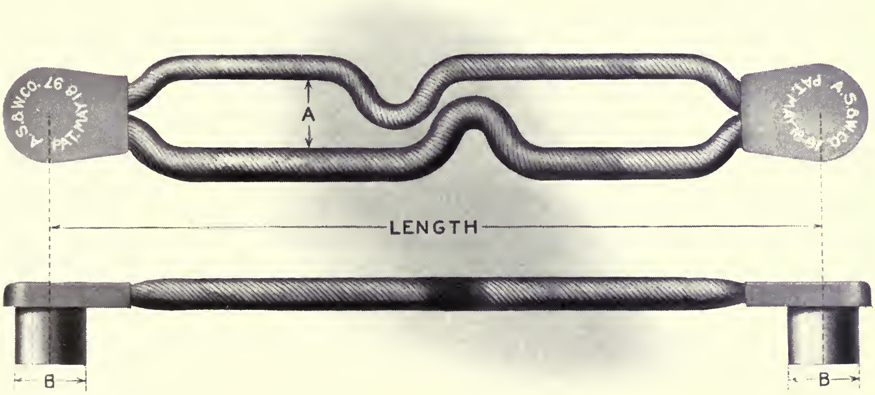


Type C. S.-06 Crown Bond

Showing a Soldered Bond Applied to Web of Rail

Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)



Type C. S.-1 Crown Bond

This type of bond differs from those shown on page 62, only in the form of terminal head, which is narrower, and in its method of connection to the strand.

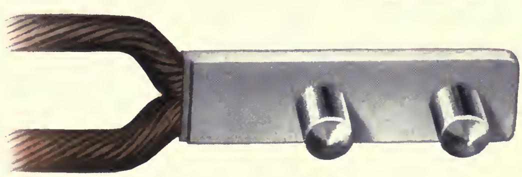
The three styles of bonds shown below are exactly similar to the one above, except in style of terminals, and they can be used in similar places.

Type C. P.-1 Crown Bond

Having tubular terminal studs for pin expansion.

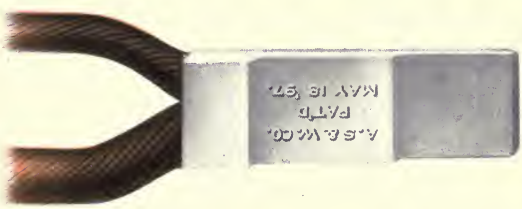
Type B. S. B.-Form C 1 Soldered Stud Bond

The termmais of this bond are furnished plain for compression or tinned for soldering, as ordered.



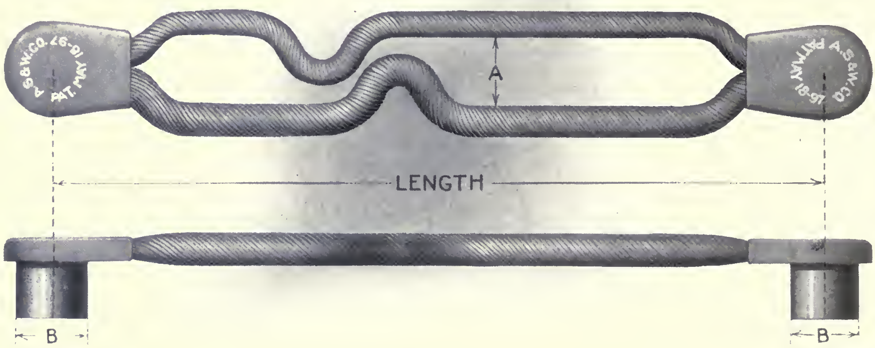
Type S. B.-Form C 1 Soldered Bond

The terminals of this bond are furnished tinned for soldering.



Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)



Type C. S.-3 Crown Bond

This type of bond differs from those shown on page 63 only in the form of terminal head, which is narrower, and in its method of connection to the strand.

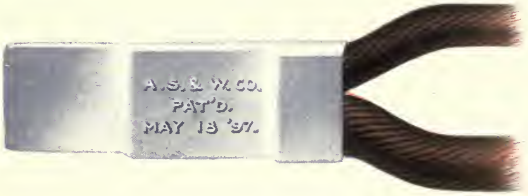
The three styles of bonds shown below are exactly similar to the one above except in style of terminals, and they can be used in similar places.

Type C. P.-3 Crown Bond

Having tubular terminal studs for pin expansion.

Type B. S. B.-Form C 3 Soldered Stud Bond

The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.

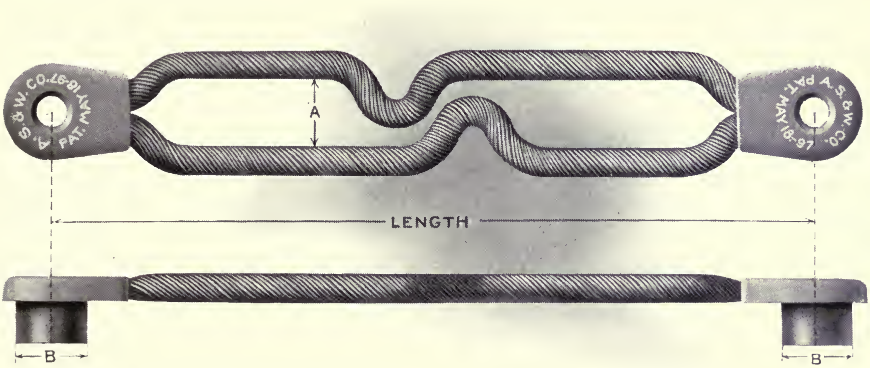


Type S. B.-Form C 3 Soldered Bond

The terminals of this bond are furnished tinned for soldering.

Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)



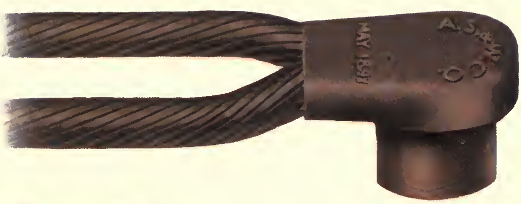
Type C. P.-2 Crown Bond

This type of bond differs from those shown on page 64 only in the form of terminal head, which is narrower, and in its method of connection to the strand.

The three styles of bonds shown below are exactly similar to the one above except in style of terminals, and they can be used in similar places.

Type C. S.-2 Crown Bond

Having solid studs for compression.



Type B. S. B.-Form C 2 Soldered Stud Bond

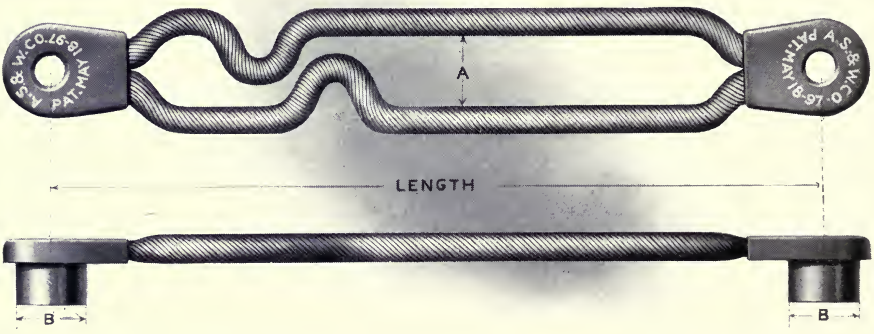
The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.

Type S. B.-Form C 2 Soldered Bond

The terminals of this bond are furnished tinned for soldering.

Concealed Rail Bonds for Rail Webs

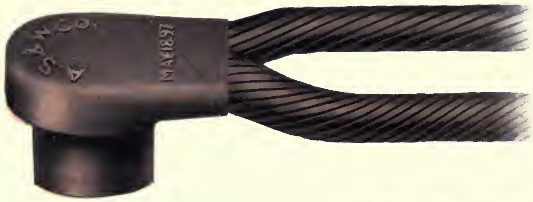
(See pages 60 and 74)



Type C. P.-4 Crown Bond

This type of bond differs from those shown on page 65 only in the form of terminal head, which is narrower, and in its method of connection to the strand.

The three styles of bonds shown below are exactly similar to the one above, except in style of terminals, and they can be used in similar places.

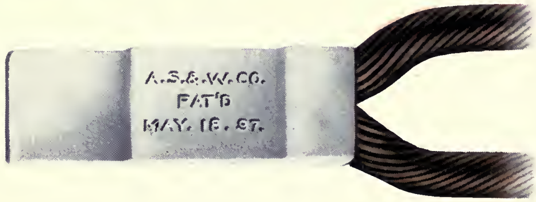


Type C. S.-4 Crown Bond

Having solid terminal studs for compression.

Type B. S. B.-Form C-4 Soldered Stud Bond

The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.

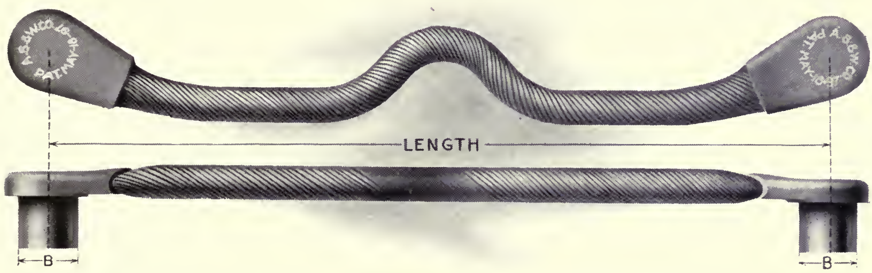


Type S. B.-Form C-4 Soldered Bond

These terminals of this bond are furnished tinned for soldering.

Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)



Type C. S.-OF Crown Bond

This single conductor bond is sometimes used under splice bars having a large bonding space beneath the track bolts and little or none above the bolts. It is a good bond to use wherever the joint construction will permit. Some advantage is gained by making this style of bond long enough to allow the terminals to project beyond the ends of the splice bars.

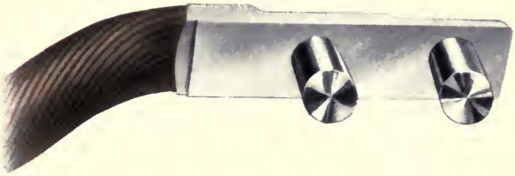
The three styles of bonds shown below are exactly similar to the above except in style of terminals, and they can be used in similar places.

Type C. P.-OF Crown Bond

Having tubular terminal studs for pin expansion.

Type B. S. B.-Form C. F. Soldered Stud Bond

The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.

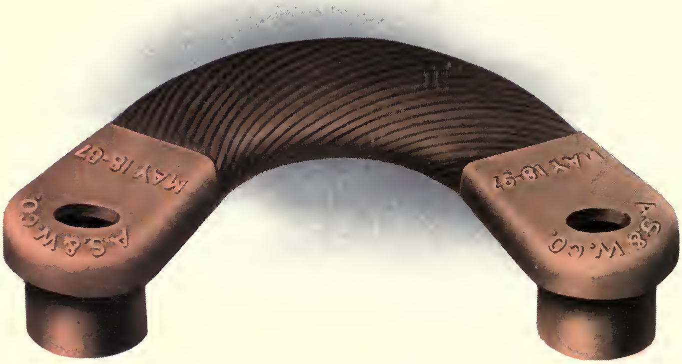


Type S. B.-Form C. F. Soldered Bond

The terminals of this bond are tinned for soldering.

Concealed Rail Bonds for Rail Webs

(See pages 60 and 74)



Type C. P. C. Crown Rail Bond

Type C. P. T. Crown Rail Bond

These bonds are made with flexible strand, either straight or crescent-shaped between terminals, as shown in the cuts. In the crescent-shaped Crown bond, type C. P. C., the curve of the strand permits the terminals to spring farther apart or closer together when the rails contract or expand. In the straight bond, type C. P. T., to provide additional length of each wire to compensate for the movement of rails, the strand is pressed back so that it bulges sidewise midway between the terminals. The standard bonds of both styles are four inches between centers of terminals, but either bond can be made in any length greater than four inches between centers, if desired. Solid terminals for compression will be furnished on order when desired.

These two types of bonds are used on the web of the rail under the splice-bar, and are especially suited to very rigid rail joints having little or no vibration.

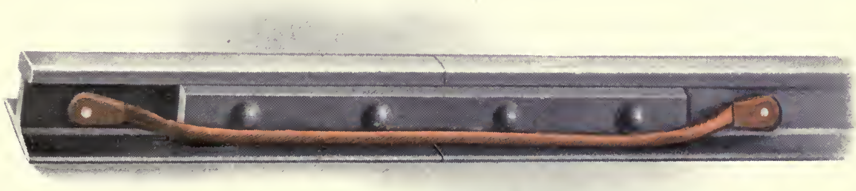
Bonds for Rail Webs

Mining Track Rail Bonds

Showing a 10-inch 2/0 Type C. P.-02 Crown Bond Applied to a Small Mining Rail

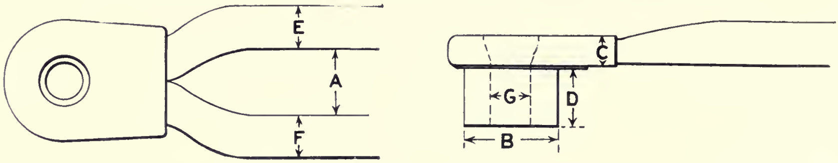
The conditions in mining tracks are so severe that special bonds are required. In general, the rails are small and there is considerable motion in the joints. The bonds must therefore be very flexible. The facilities for working about rail joints are poor, owing to the confined space and absence of light. Therefore the bonds should be easy to apply. As the cars frequently jump the track, the bonds should be protected. Finally the bonds must be efficient and lasting.

The two styles of bonds shown on this page will fully meet all these requirements. In laying new track rails, 25 pounds per yard or larger, we would recommend the special Type C. P.–02, shown above, having extremely flexible conductors. For small rails or for bonding old tracks the Type C. P. F. bond should be used as shown below. The strand of this bond can be placed below the heads or nuts of track bolts, where they will be protected from injury.



Showing a 22-inch 2/0 Type C. P. F. Crown Bond Applied Over Plate of Small Rail

Concealed Rail Bonds for Rail Webs



Standard Dimensions of Crown Rail Bonds

Table IX

Bond Terminals

All Dimensions in Inches

Size of Bond	Outside Diameter B of Stud	Solid Stud Terminals		Tubular Stud Terminals		
		Length of Stud under Head, D	Thickness of Crown or Head, C	Length of Stud under Head, D	Thickness of Crown or Head, C	Diameter of Hole Through Stud, G
1/0	½	¾	¼	$\frac{9}{16}$	¼	$\frac{2}{10}$
2/0	⅝	¾	$\frac{9}{32}$	$\frac{9}{16}$	$\frac{9}{32}$	$\frac{9}{32}$
3/0	¾	¾	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{11}{32}$
4/0	⅞	¾	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{13}{32}$
300,000 C. M.	1	¾	⅜	⅝	⅜	$\frac{9}{16}$
500,000 C. M.	1	¾	⅜	⅝	⅜	$\frac{9}{16}$

Bond Conductors

Duplex Parallel Bonds

Size of Bond	Distance Between Conductors A	Unbalanced Bonds						Balanced Bonds		
		Smaller Strand			Larger Strand			No. of Wires in each Strand	Dia. of each Strand	Capacity of each Strand
		No. Wires	Dia. Strand	Capacity	No. Wires	Dia. Strand	Capacity			
1/0	¾	..	..	.....	..	..	.....	19	.28	53,000
2/0	⅞	19	.28	50,000 C.M.	37	.36	86,000 C.M.	37	.32	67,000
3/0	⅞	37	.32	65,000 C.M.	61	.40	105,000 C.M.	37	.36	86,000
4/0	⅞	37	.36	88,000 C.M.	61	.44	125,000 C.M.	61	.40	106,000
300,000 C. M.	⅞	61	.44	125,000 C.M.	91	.51	175,000 C.M.	91	.47	150,000
500,000 C. M.	1	127	.56	210,000 C.M.	127	.65	290,000 C.M.	127	.61	250,000

Single Strand Bonds

Size of Bond	Number of Wires	Diameter over Strand	Pitch of Strand in Diameters Degrees	Size of Bond	Number of Wires	Diameter over Strand	Pitch of Strand in Diameters Degrees
1/0	27	.41	20	4/0 B. & S. G.	37	.56	20
2/0	37	.45	20	300,000 C. M.	61	.67	20
3/0	37	.50	20	500,000 C. M.	91	.85	20

Concealed Rail Bonds for Rail Webs

We give below in tabulated form the particular size, type and length of duplex parallel Crown bonds best suited to *standard* rail sections and drillings as given in the latest editions of rail catalogues issued by the Carnegie Steel Company and the Lorain Steel Company. Any style of terminals can be used equally well on these bonds. The capacity of the bond is such that there will be approximately $\frac{1}{64}$ inch clearance about each strand in a new rail joint. If the rail drilling differs from the standard as given on pages 177 and 179, the bonds can be lengthened or shortened in proportion, so as to bring the bond terminals midway between the bolt holes.

A. S. C. E. T-Rail Sections

Table X

Rail Section Pounds	Capacity of Bond in Circular Mils	Capacity of Strands in Circular Mils		Length of Bond Inches		Form Number of Bond	
		Smaller Strand	Larger Strand	Single Bonding	Double Bonding	Single Bonding	Double Bonding
50	132,716	66,358	66,358	10	14	2	4
60	150,052	66,358	83,694	10	14	01	03
70	167,388	83,694	83,694	10	14	02	04
75	167,388	83,694	83,694	10	14	02	04
80	216,773	83,694	133,079	10	14	01	03
85	238,704	105,625	133,079	10	14	01	03
90	238,704	105,625	133,079	10	14	01	03
100	238,704	105,625	133,079	10	14	01	03
110	300,851	133,079	167,772	10	14	01	03

Series "A" and "B" T-Rails

(See page 177)

60	167,388	83,694	83,694	10	14	2	4
70	167,388	83,694	83,694	10	14	2	4
80	266,158	133,079	133,079	10	14	2	4
90	211,250	105,625	105,625	10	14	2	4
100	211,250	105,625	105,625	10	14	2	4

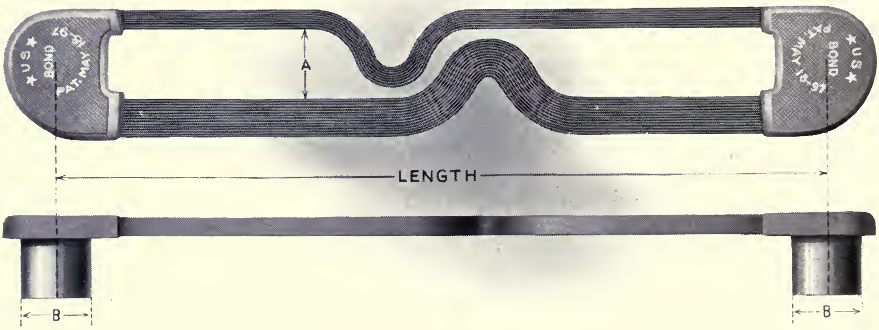
Lorain Girder Rails

(See page 179)

73	266,158	133,079	133,079	9	13	02	04
90	266,158	133,079	133,079	9	14	02	04
95	266,158	133,079	133,079	9	13	02	04
116	266,158	133,079	133,079	9	13	02	04
129	335,544	167,772	167,772	10	14	02	04

Concealed Rail Bonds for Rail Webs

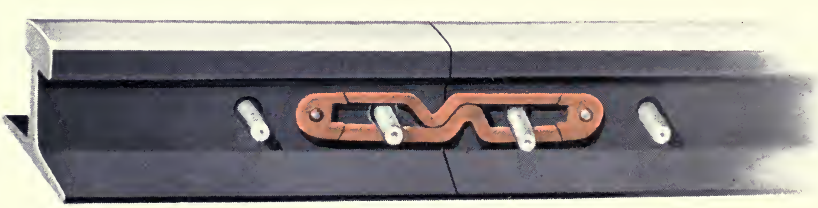
(See pages 60 and 85)



Type U. S.-01 United States Bond

The United States rail bonds have their flexible conductors made of flat parallel laid ribbons of annealed copper. They are adapted for use in rail joints having narrow spaces between the joint plates and rail web, as already explained on page 27. The bonds shown here are used largely for single bonding on rail joints having a larger bonding space below than above the track bolts. The terminals are usually placed midway between the first and second bolts. Made in any length or capacity.

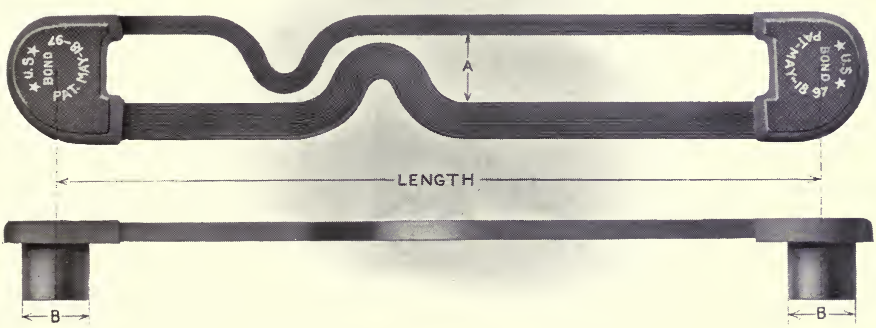
Type U. P.-01 United States Bond



Showing a Type U. P.-01 United States Bond Installed on a Rail

Concealed Rail Bonds for Rail Webs

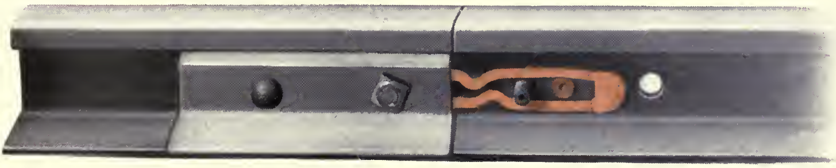
(See pages 60 and 85)



Type U. S.-03 United States Bond

The bonds shown here are used largely for double bonding on rail joints having a larger bonding space below than above the track bolts. One terminal is usually placed between the first and second bolt holes of one rail, and the other is placed between the second and third bolt holes of the other rail, the two bonds being staggered. The long open space between the conductors at one end of the bond provides room for one track bolt and one terminal of the opposite bond, as shown below. Made in any length or capacity.

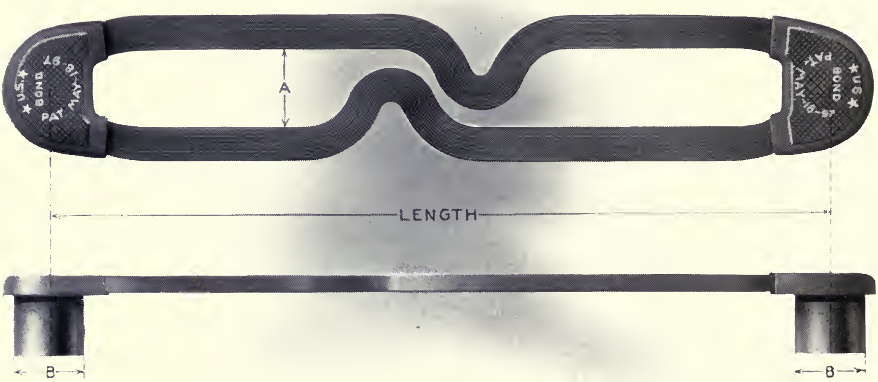
Type U. P.-03 United States Bond



Showing Type U. S.-03 United States Bond Installed on a Rail

Concealed Rail Bonds for Rail Webs

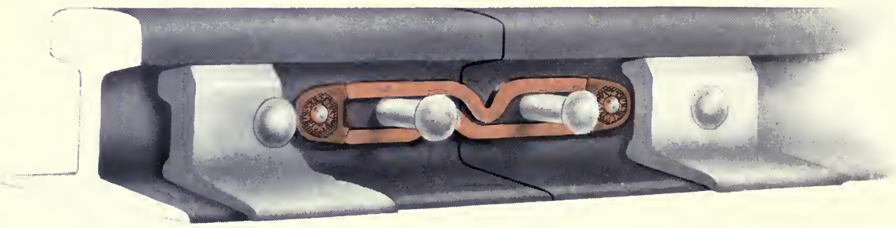
(See pages 60 and 85)



Type U. S.-02 United States Bond

These bonds are used largely for single bonding on rail joints having equal bonding spaces above and below the track bolts. The terminals are usually placed midway between the first and second bolt holes. Made in any length or capacity.

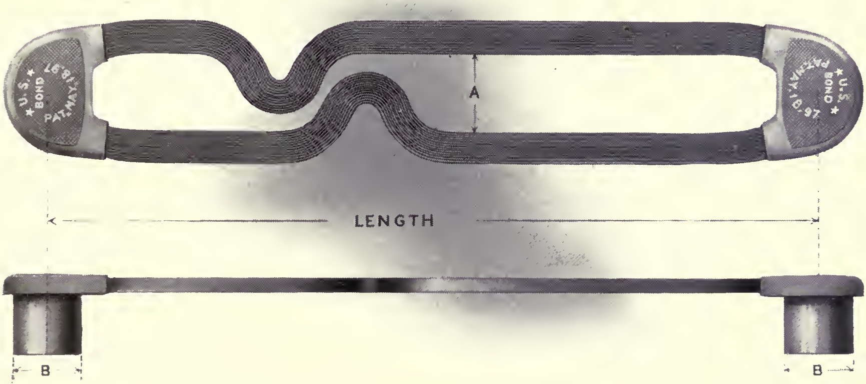
Type U. P.-02 United States Bond



Showing a Type U. P.-02 United States Bond Installed on a Rail

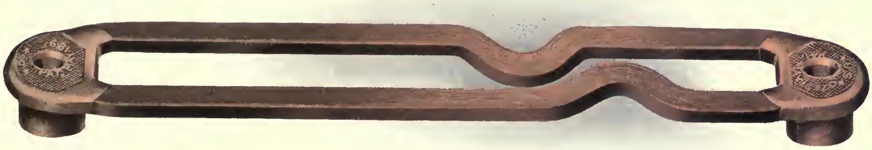
Concealed Rail Bonds for Rail Webs

(See pages 60 and 85)

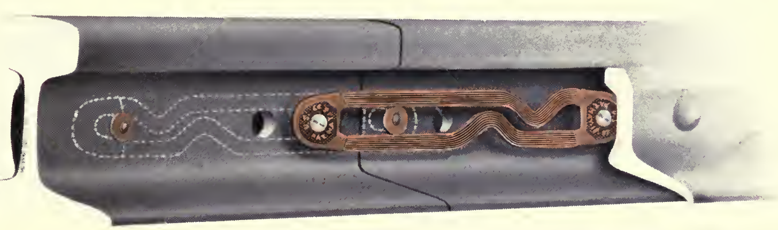


Type U. S.-04 United States Bond

The bonds shown here are used largely for double bonding on rail joints having equal bonding spaces above and below the track bolts. One terminal is usually placed midway between the first and second bolt holes of one rail, and the other terminal is placed between the second and third holes of the other rail, the two bonds being staggered. The long open space between the conductors at one end of the bond provides ample room for one bolt and one terminal of the bond on the other side of the rail. Made in any length and capacity required.

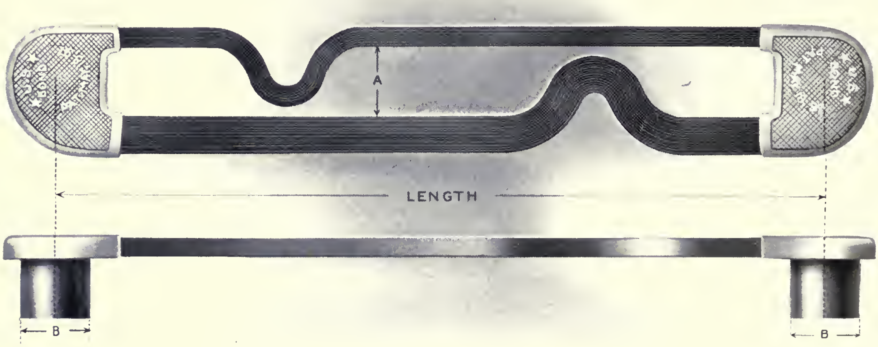


Type U. P.-04 United States Bond



Type U. P.-04 Bond Attached to Web of a Rail

Concealed Rail Bonds for Rail Webs



Type U. S.-05 United States Bond

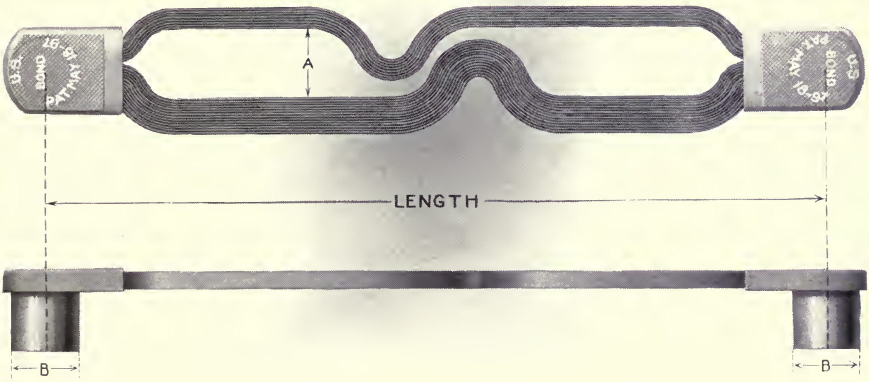
This form of bond is used for single bonding or for double bonding. Except in very special cases, this style of forming the conductor loops is not as satisfactory as those shown on the two preceding pages, and on this account none of the other styles of United States bonds shown will have this form of loop, but any of them may be so formed upon request.

Type U. P.-06 United States Bond

Type U. S.-06 United States Bond Applied to a Rail

Concealed Rail Bonds for Rail Webs

(See pages 60 and 85)



Type U. S.-1 United States Bond

This type of bond differs from those shown on page 76 only in the form of terminal head, which is narrower, and in its method of connection to the conductor.

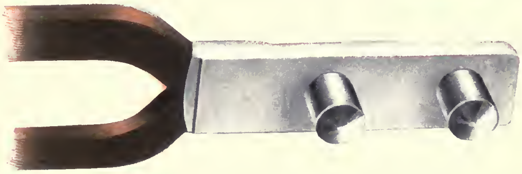
The three styles of bonds shown below are exactly similar to the one above, except in style of terminals, and they can be used in similar places.

Type U. P.-1 United States Bond

Having tubular terminal studs for pin expansion.

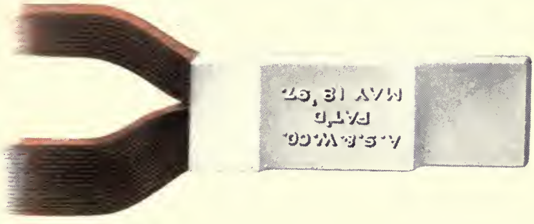
Type B. S. B.-Form U 1 Soldered Stud Bond

The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.



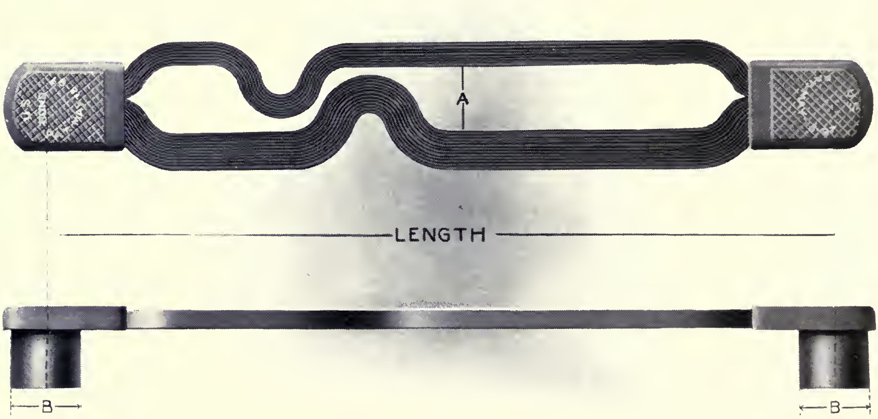
Type S. B.-Form U 1 Soldered Bond

The terminals of this bond are furnished tinned for soldering.



Concealed Rail Bonds for Rail Webs

(See pages 60 and 85)



Type U. S.-3 United States Bond

This type of bond differs from those shown on page 77 only in the form of terminal head, which is narrower, and in its method of connection to the conductor.

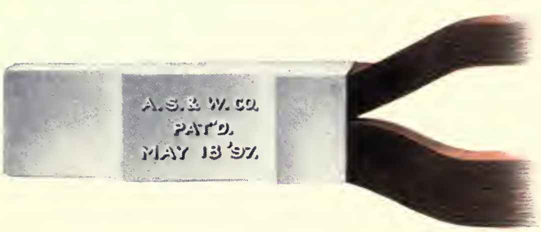
The three styles of bonds shown below are exactly similar to the one above, except in style of terminals, and they can be used in similar places.

Type U. P.-3 United States Bond

Having tubular terminal studs for pin expansion.

Type B. S. B.-Form U 3 Soldered Stud Bond

The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.

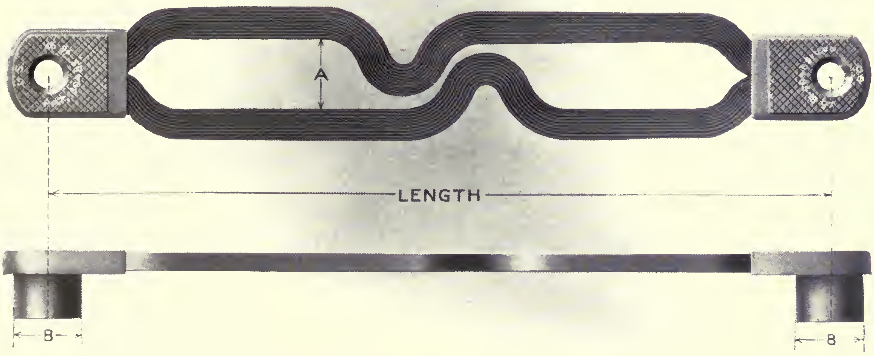


Type S. B.-Form U 3 Soldered Bond

The terminals of this bond are tinned for soldering.

Concealed Rail Bonds for Rail Webs

(See pages 60 and 85)



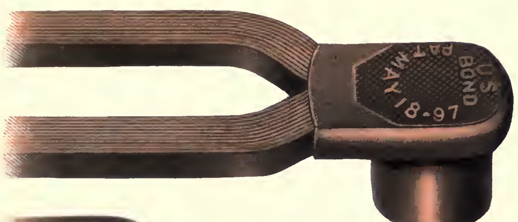
Type U. P.-2 United States Bond

This type of bond differs from those shown on page 78 only in the form of terminal head, which is narrower, and in its method of connection to the conductor.

The three styles of bonds shown below are exactly similar to the one above except in style of terminals, and they can be used in similar places.

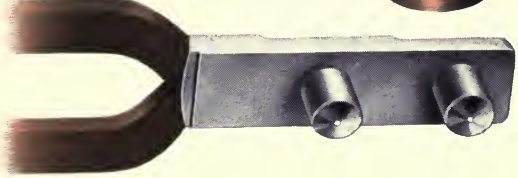
Type U. S.-2 United States Bond

Having solid studs for compression.



Type B. S. B.-Form U 2 Soldered Stud Bond

The terminals of this bond are furnished plain for compression, or tinned for soldering, as ordered.

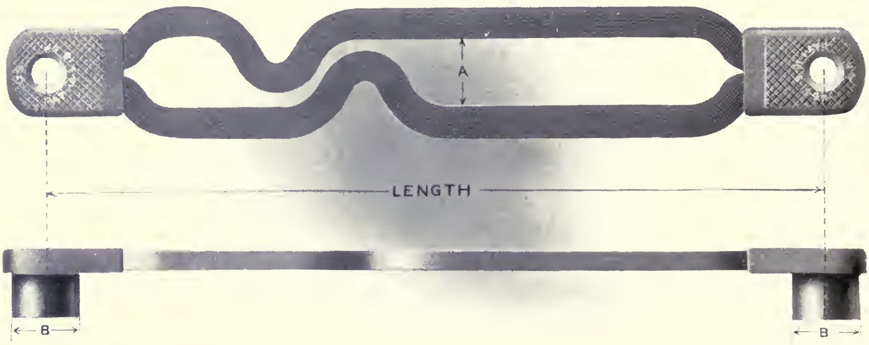


Type S. B.-Form U 2 Soldered Bond

The terminals of this bond are tinned for soldering.

Concealed Rail Bonds for Rail Webs

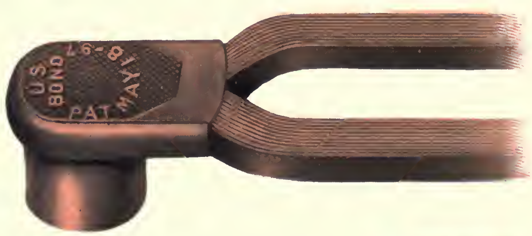
(See page 60)



Type U. P.-4 United States Bond

This type of bond differs from those shown on page 79 only in the form of terminal head, which is narrower, and in its method of connection to the conductor.

The three styles of bonds shown below are exactly similar to the one above, except in style of terminals, and they can be used in similar places.



Type U. S.-4 United States Bond

Having solid terminal studs for compression.

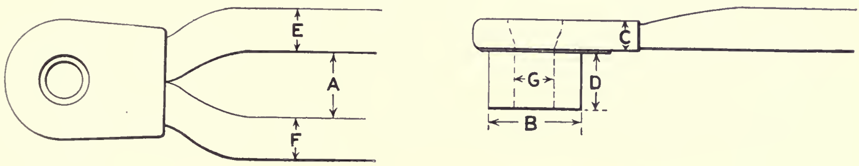
Type B. S. B.-Form U 4 Soldered Stud Bond

The terminals of this bond are furnished plain for compression or tinned for soldering, as ordered.

Type S. B.-Form U4 Soldered Bond

The terminals of this bond are tinned for soldering.

Concealed Rail Bonds for Rail Webs



Standard Dimensions of United States Rail Bonds

Table XI

Bond Terminals

All Dimensions in Inches

Size of Bond	Outside Diameter B of Stud	Solid Stud Terminals		Tubular Stud Terminals		
		Length of Stud Under Head D	Thickness of Crown or Head C	Length of Stud Under Head D	Thickness of Crown or Head C	Diameter of Hole Through Stud G
1/0 B. & S. G.	½	¾	¼ to 9/32	9/16	¼ to 9/32	2/10
2/0 B. & S. G.	⅝	¾	¼ to 9/32	9/16	¼ to 9/32	9/32
3/0 B. & S. G.	¾	¾	¼ to 9/32	9/16	¼ to 9/32	11/32
4/0 B. & S. G.	⅞	¾	¼ to 9/32	9/16	¼ to 9/32	13/32
300,000 C. M.	1	¾	⅜	⅝	⅜	9/16

Bond Conductors

Duplex Parallel Bonds

Size of Bond	Unbalanced Bonds					Balanced Bonds Distance Between Conductors (A) = 1 Inch. Forms 02 to 06	
	Distance Between Conductors A	Smaller Conductor		Larger Conductor			
		Number Strips	Capacity	Number Strips	Capacity	Number of Strips in Each Conductor	Capacity Each Conductor
1/0 B. & S. G.	¾	4	36,000 C. M.	8	70,000 C. M.	7	53,000 C. M.
2/0 B. & S. G.	⅞	6	53,400 C. M.	9	81,000 C. M.	9	67,000 C. M.
3/0 B. & S. G.	⅞	7	62,000 C. M.	12	106,000 C. M.	11 & 12	86,000 C. M.
4/0 B. & S. G.	⅞	9	80,000 C. M.	15	132,000 C. M.	14	106,000 C. M.
300,000 C. M.	1	10	115,000 C. M.	16	185,000 C. M.	13	150,000 C. M.

Exposed Bonds for Bridging Splice Bars

(See pages 60 and 74)

A long rail bond extending around the splice bar and attached to the web of rails can often be used to better advantage than any other type of bond, as explained on page 30. This style is especially serviceable on small rails in mines where there would not be sufficient room for bonds underneath the splice bars; and for rebonding old rails in paved streets, in which case it is not necessary to disturb the plates. Several types will be shown on this and the next two pages. They are made of any length or capacity required.

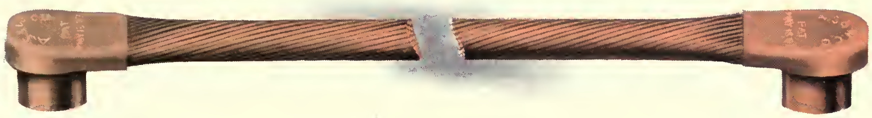
Type C. S. S. Crown Bond

These are "one-piece" bonds, the terminals being forged from the solid conductor. They are provided with either solid or tubular terminals. The extended length of these bonds should be 1½ inches more than the distance between bond holes, to allow for forming.

Showing a Type C. P. S. Crown Bond Applied to a Rail

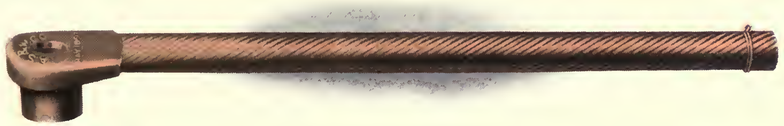
Exposed Bonds for Bridging Splice Bars

(See pages 60 and 74)



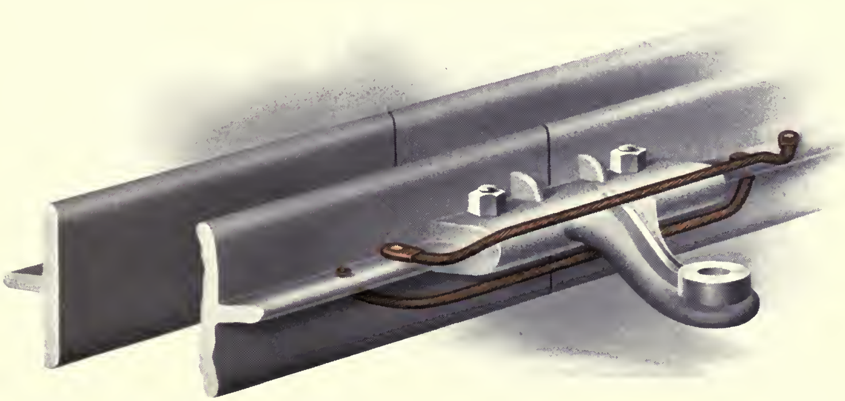
Type C. S. F. Crown Bond

This type of bond is very similar to the Type C. S.–O. F. series, shown on page 71. It is a very flexible and serviceable bond for any special or exposed track bonding. Also made with tubular terminals as shown below. Made in any length or capacity.



Type C. P. F. Stub End Crown Bond

Stub End Bonds Are made to any length or capacity, and though we have shown here but one style of terminal, it will be understood that stub end bonds can be made with any of our regular terminals.



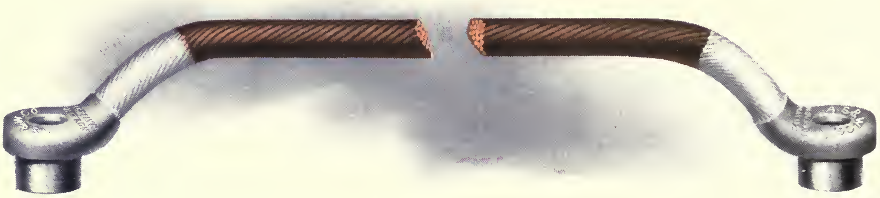
Type C. P. F. Crown Bonds Applied to Conduit Rails

Exposed Bonds for Bridging Splice Bars

(See pages 60 and 74)

Type C. S.-O. G. Crown Bond
(Patented)

These make an extremely flexible and serviceable bond for bridging splice bars or for other purposes. The portions of the strand adjacent to the terminals are bent out to clear the splice bars and then dipped in molten solder, which renders this portion of the bond conductor stiff enough to retain this form indefinitely. Its extended length is about 1¼ inches longer than the distance between bond holes.



Type C. P.-O. G. Crown Bond

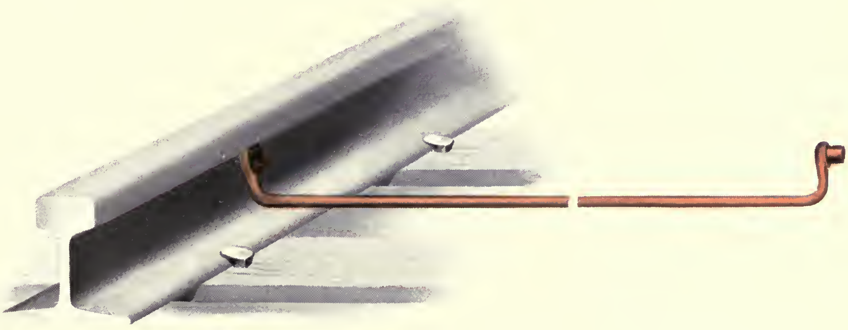
The "Chicago Bond"

The Chicago bond, of which we have always been the only makers, was the first type to be provided with enlarged tubular terminals, and from this have been developed all Crown bonds having pin expanded terminals. This is a one-piece bond, suitable for spanning joint plates. Made in any length or capacity up to 4/0, and furnished with expanding pins.

Type C. P. X. Crown Bond
Used for Cross Bonding

It is advisable to bond together at frequent intervals the two rails of a track, or the several parallel tracks of a system, by means of cross bonds. These aid materially in preventing open track circuits. For this purpose we supply the two Crown bonds here shown. On interurban roads it is advisable to use ten or more of these bonds per mile, while in city streets with heavy traffic, they should be placed much nearer together.

Made in any length, though generally about five inches longer than the track gauge.

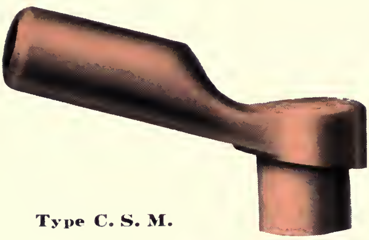


Application of Type C. S. X. Crown Bond to Rail

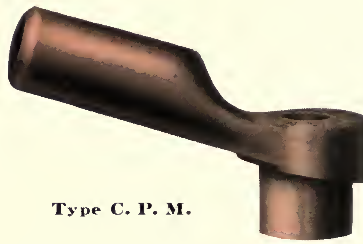
NOTE—We make other bonds similar in form to types C. S.-O. G. and C. P.-O. G. shown on opposite page. The terminal shoulders of these extend back on the conductor to a considerable distance, and the ends of the bonds are not dipped in solder. This bond provided with solid terminals is known as *type C. S.-G. Crown bond* and the tubular terminal bond is called *type C. P.-G. Crown bond.*

Socket Terminals

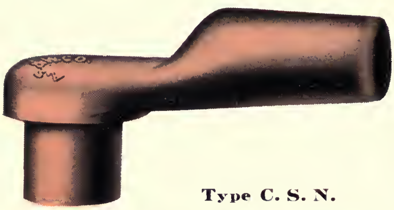
These terminals can be used in many places where it would be inconvenient to order special lengths of bonds. The various styles of terminal shanks shown are provided with deep sockets, into which the conductors, cut to proper length, may be soldered by the purchaser. Standard terminals of these designs are made with studs having diameters of $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$ and 1 inch. The sockets in every case are drilled to fit the conductor, as ordered.



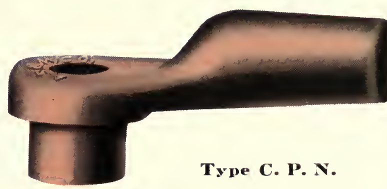
Type C. S. M.



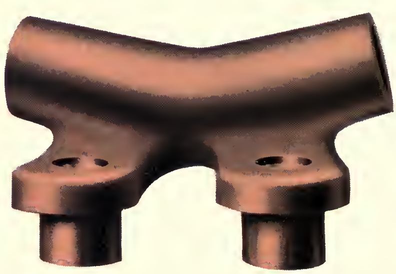
Type C. P. M.



Type C. S. N.



Type C. P. N.



Type C. P. N. D. Duplex Crown Socket Terminal

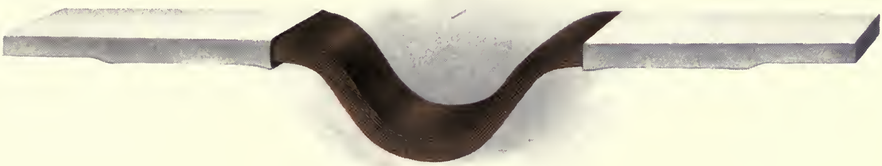
Type C. S. O.

Type C. P. O.

Rail Bonds for Rail Flanges

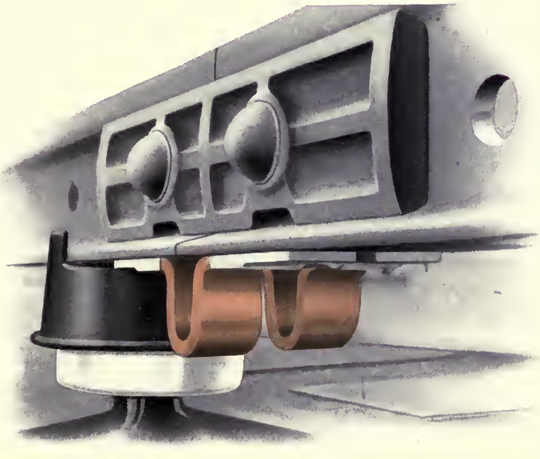
(See pages 19 and 58)

Under certain conditions, bonds can be advantageously applied to the flanges of rails. This is especially true of feeder rails, which being elevated on insulators, are easy of access, and which are comparatively free from severe vibrations. In general, feeder rails require short heavy bonds of high conductance, such as the type B. S. B., form A bond (see page 56) applied to the rail head, or either of the following bonds which is attached to the flange.



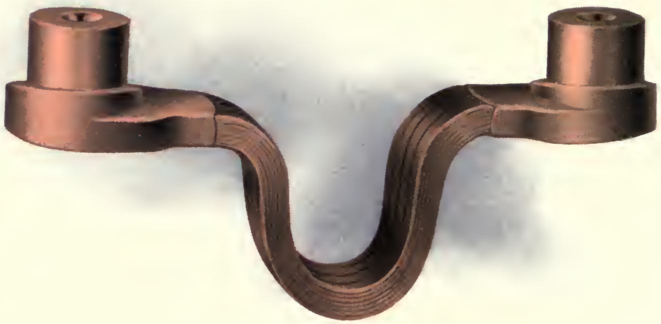
Type S. B.-Form 2 Soldered Bond

No other soldered bond has given such efficient and lasting service as this which is attached to the under side of the flange. This bond is often made large in capacity.



Type S. B.-Form 2 Soldered Bond Applied to Third Rail

Rail Bonds for Rail Flanges



Type U. S. B. United States Bond—Single Loop

The bond here shown is designed for the under side of the flange of rails. The crown of the terminal is beveled to bring the axis of the terminal perpendicular to the upper surface of the rail flange. The terminals are connected by a conductor built up of layers of thin copper ribbons bent into either of the two forms shown. The standard formed length of this bond is five inches. Using our hydraulic punch and compressor, shown on pages 126 to 130, this bond can be quickly and effectively installed. The bond is specially suitable for feeder rails, and is made in any size up to 500,000 circular mils.

Type U. S. B. United States Bond Applied to Rail—Double Loop

Part III

Bonding Tools and Appliances

The durability and efficiency of a rail bond installation, as well as its cost, will depend to a large extent upon the effectiveness of the tools used. No workmen can do good work with poor bonding tools. We were the pioneers in the manufacture of rail bonds and our extensive and thorough experience has enabled us to develop the complete series of perfected tools shown in this section. First and foremost our aim has been to produce tools of the greatest effectiveness and suitability for the service to which they are to be put; to make them perfect in every detail, and as strong, durable and reasonable in cost as possible. With the exception of the small hand tools, which are sold only, all of the bonding tools shown are sold or rented to customers using our rail bonds.

We solicit your correspondence and shall be pleased to quote you on rail bonds or bonding tools.

Drilling Machines

To drill a bond hole in a rail as it should be drilled, exact to size, with smooth surfaces, fitting closely the terminal of the bond to be used, the drilling machine must be attached rigidly to the rail. Its parts must be strong and durable to resist wear, and they must be accurately and closely adjusted. The various styles of drilling machines here shown meet these requirements in every particular. They are unique and simple in their design and construction and make a long step forward in the evolution of rail bonding. Easily handled and operated, they work rapidly and accurately. All machines shown (except Nos. 19 and 21-M) are rigidly attached to the rails with a vise-like grip. Those which are attached to the head of the rail can easily be placed in position or removed in eight (8) seconds, and without disturbing the joint plates. Each machine has a positive automatic feeding device which can be controlled at will. The drills are operated with a vertical hand lever or with a 600-volt D. C. series wound electric motor. It has been demonstrated beyond question that a man can do a given amount of drilling much easier by operating a lever than he can by turning a crank.

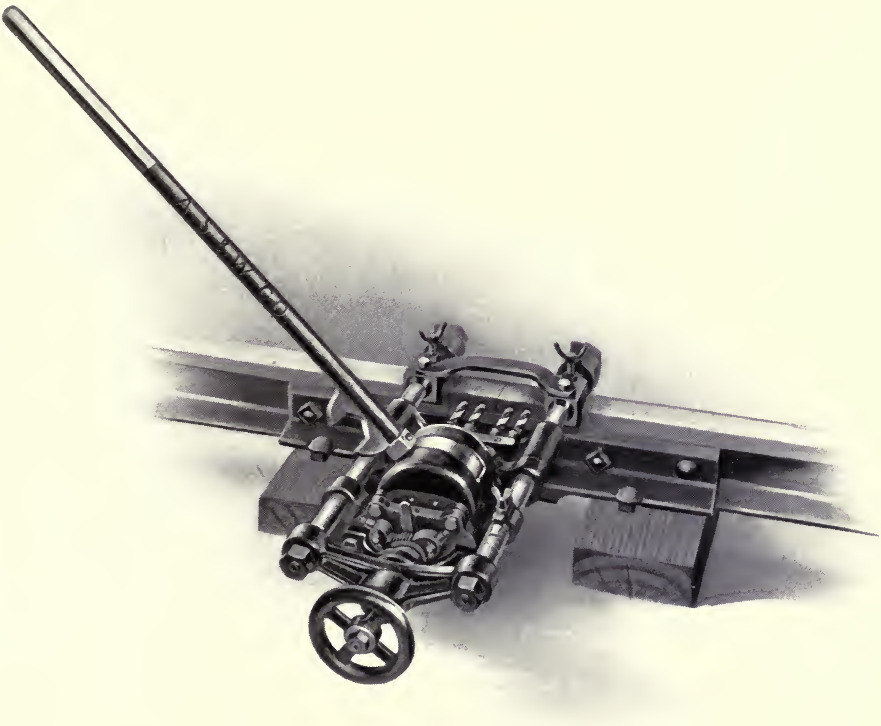
In every hand-operated machine each half stroke of the lever rotates all drills forward through equal angles of rotation. In all multiple-spindle drilling machines each separate spindle is provided with an adjusting nut so that each drill can be adjusted independently of the others. This provision offsets uneven wearing of drills or setting of rails. The drill points are held rigidly in the machine and therefore seldom break or chip. For the same reason the holes may be started without first prick punching the rail.

No. 22 Drill Being Operated by Two Men

Where necessary the machines are equipped with gauges for determining the correct depth of holes, and with screws to raise or lower the frames quickly so as to bring the drill points into their correct position. The levers by which the machines are operated are detachable and in many cases serve as handles for carrying the tools, and as wrenches for attaching the drills to the rails. Each drilling machine is equipped with all fittings and one set of new drills. Many parts of these machines are interchangeable and small parts may be ordered by mail.

Drilling Machines

Parts should be ordered by part numbers as shown on later pages. All parts are made of high grade steel, and machined accurately to size.



Four-Spindle Drill, Type No. 22

The hand-operated double-twin drill shown above is one of the most perfect machines ever constructed. It drills at one time all four holes for the twin terminal bond. Two men can operate this machine and drill the holes for eight joints per hour. This reduces the cost of installing the twin terminal bonds to a very low figure. The drill grips the head of the rail rigidly and it can be placed in position without disturbing the splice bars.

Weight of machine complete approximately 125 pounds.

See next page.

Directions for Operating Type 22 Four-spindle Hand-operated Drill

Place clamping bars 22 over head of rail and adjust vertically for drilling by means of adjusting screws 27. Holes should be high enough on rail head to leave at least $\frac{3}{32}$ inch of steel in lower edge. Clamp machine to rail tight

Drilling Machines

Directions for Operating No. 22 Drill—Continued

enough to hold securely, but not tight enough to break the clamping bar, with handle wrench 34, on clamping nuts 25. Machine should be level with track. Run drill points up to rail by means of hand wheel 9, and adjust drills by means of adjusting nuts 41, so that all four drills will press against rails. Keep all the adjusting nuts 41 well back on spindles so as to afford good driving seats for twist drill shank.

Set depth gauge 29 to nearest index mark on guide bars 22. Turn pawl cam 15 to mesh feed pawls 18 with feed ratchet gear 13, so that the drills will feed into rail automatically. Place handle lever 34 on driving stud 31 and operate, drilling holes in rail to required depth, which will be shown when depth gauge travels to next index mark on guide bars. *Exact depth of holes is important.*

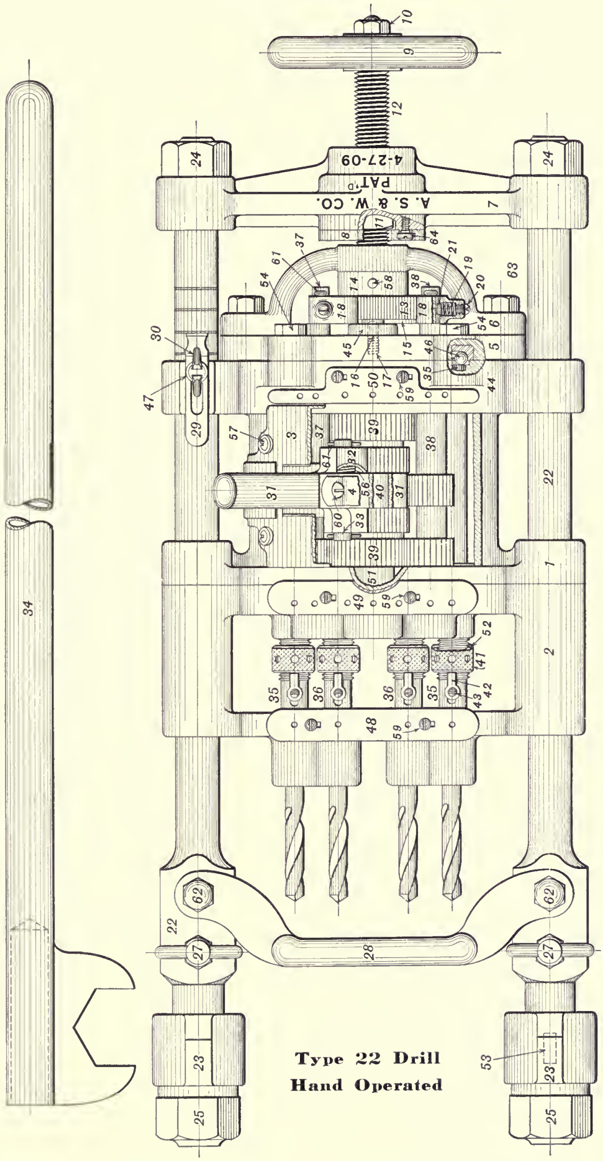
Lift feed pawls out of mesh with feed ratchet gear by means of pawl cam 15. Then feed drills back from rail with hand wheel 9, loosen clamping nuts, remove machine from rail, move to next joint, and repeat.

To remove twist drill from drill spindles, loosen set screw 43 on clamp dogs, then pull out the drill. Drills must be kept sharp and ground at proper angles at all times, else much trouble will result, and the machine may be broken. In grinding drills duplicate the exact shape of a new drill point. While use of oil on drill points is optional with customers, the life of the machine and the drills will be much prolonged by using lard oil, and the machine will work easier. The holes can easily be cleaned with gasoline. (See page 24.) Keep the machine clean and free from sand, and well oiled with good machine oil. This machine can be operated with any one or two drills removed.

Parts for Type 22 Drill

1 Large part of body (back) casting.
2 Small part of body (front) casting.
3 Gear cover, casting.
4 Springs on gear cover.
5 Truss plate on back part of body.
6 Small yoke for feed screw.
7 Large yoke for feed screw.
8 Plate on large yoke (outside of brass nut).
9 Hand wheel.
11 Brass nut on feed screw.
12 Feed screw.
13 Feed ratchet gear.
14 Collar on feed screw.
15 Cam for feed pawls on feed screw.
16 $\frac{5}{16}$-inch plunger for cam in truss plate.
17 Spring for plunger in truss plate.
18 Feed pawls.
19 Spring for feed pawls.
20 $\frac{5}{16}$-inch headless set screw in pawls.
21 Brass friction in feed pawls.
22 Guide and clamping bar for machine.
23 Loose jaw on guide bar (clamp).
24 1-inch nut on guide bar (clamp).
25 $1\frac{7}{16}$-inch nut on guide bar (clamp).
26 Washer on guide bar (clamp).
27 Adjusting screw on guide bar.
28 Tie for guide bar (clamp).
29 Depth gauge for drilling.
30 Thumb nut for depth gauge.
31 Driver lever for driving machine.
32 Pawl for drive lever.
33 Stud for drive lever, pawl stud.
34 Handle and wrench for drive.
35 Single gear spindle.
36 Double gear spindle.
37 Intermediate gear.
38 Intermediate gear staggered teeth.
39 Ratchet driving gears.
40 Shaft for drive gears.
41 Adjusting nuts on spindle.
42 Clamps (dogs) for holding drills.
43 $\frac{1}{4}$-inch headless set screws for dogs on spindle.
44 Ball race in truss plate.
45 Truss block for feed screw.
46 $\frac{3}{8}$-inch balls.
48 Oil hole cover (front body).
49 Oil hole cover (back body).

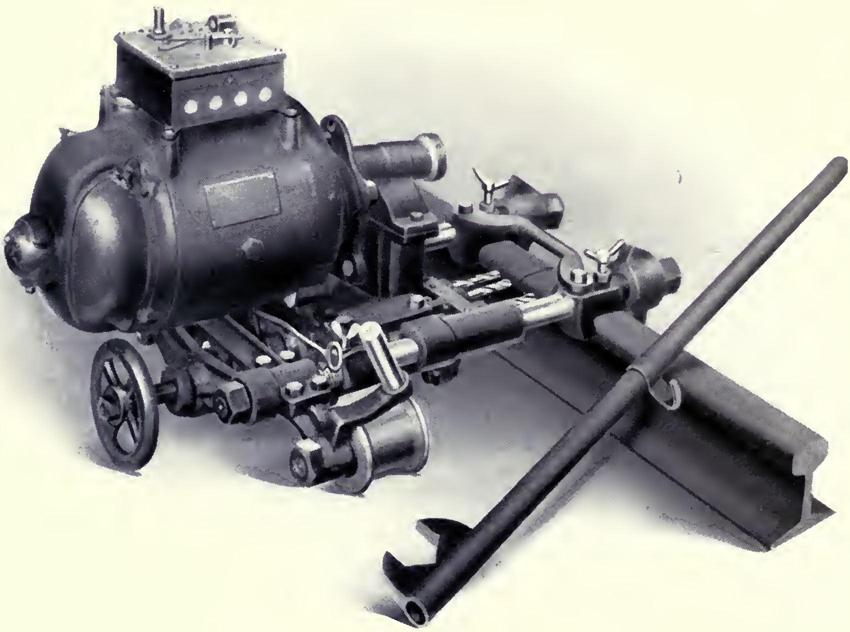
Drilling Machines



Type 22 Drill
Hand Operated

50 Oil hole cover (back body).
51 Collar on driving shaft.
52 Friction spring on adjusting nut on spindles.
53 Woodruff key for guide bars.
54 ½-inch cap screw in truss plate.
56 Spring for driving pawls.
58 $\frac{3}{16}$-inch pins for collar on feed screw.
62 ½-inch cap screws for small and large part of body truss plate and tie on guide bars.
63 ⅝-inch cap screw for small yoke.
64 $\frac{5}{16}$-inch Fil. screws for plate on large yoke outside brass nut for feed screw.

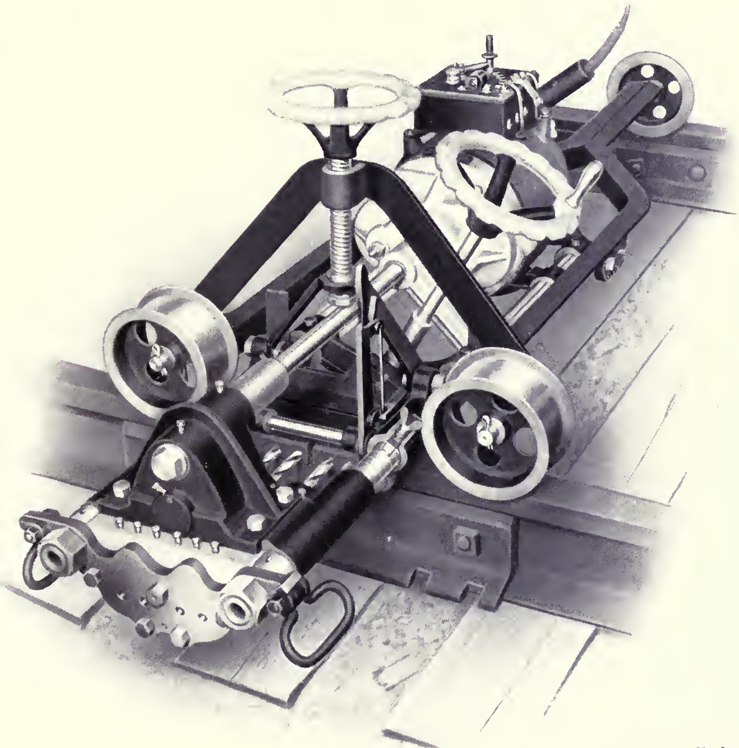
Drilling Machines



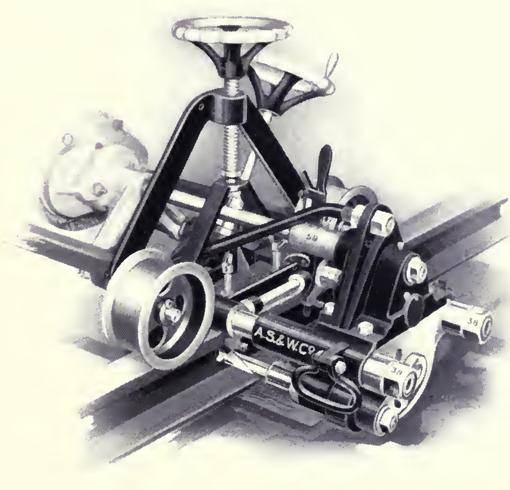
Motor Drill, Type 22 M

The four-spindle motor drill shown above is one of the most perfect machines ever constructed. It drills at one time all four holes in the head of a rail for our standard twin terminal bond. The construction of the drilling machine is the same as for drill No. 22, already explained on preceding pages. Two men can easily handle this machine and drill holes for seventeen or more joints per hour. This reduces the cost of installing twin terminal bonds to an extremely low figure. The series wound motor built specially for this drill is light and compact and will operate directly on a 600-volt trolley circuit. The internal windings are thoroughly well protected and insulated, and the armature shaft is geared direct to the drill spindles. The machine, having two small carriage wheels, can be placed on the rail and moved easily from joint to joint, or it can be carried about by means of the handle which hooks into the motor frame. Weight of machine approximately 300 pounds.

Drilling Machines



Four-Spindle Motor Drill, Type 022 M



Single Spindle Motor Drill Type 021 M

Drilling Machines

The 022 M and 021 M Motor Drill

An entirely new design of four-spindle motor drill has been developed for our Twin Terminal Bond, as shown on preceding page. While this new machine weighs but little more than our old drill (shown on page 98) and can readily be carried about by three men, it is much stronger, more durable and more easily handled. It is carried on a light three-wheel truck, and is so designed that all adjustments and operations can be made easily and quickly. It is fed by hand, the correct depth of holes can readily be determined by a plainly marked index, and the gearing which runs in a grease tight casing is pratically noiseless and frictionless. All four holes can be drilled in about one minute, and it requires less than a minute to set the machine, thus bringing the cost of drilling down to a very low figure. It is operated by a 600-volt D. C. series wound motor of ample capacity for the work and of standard make.

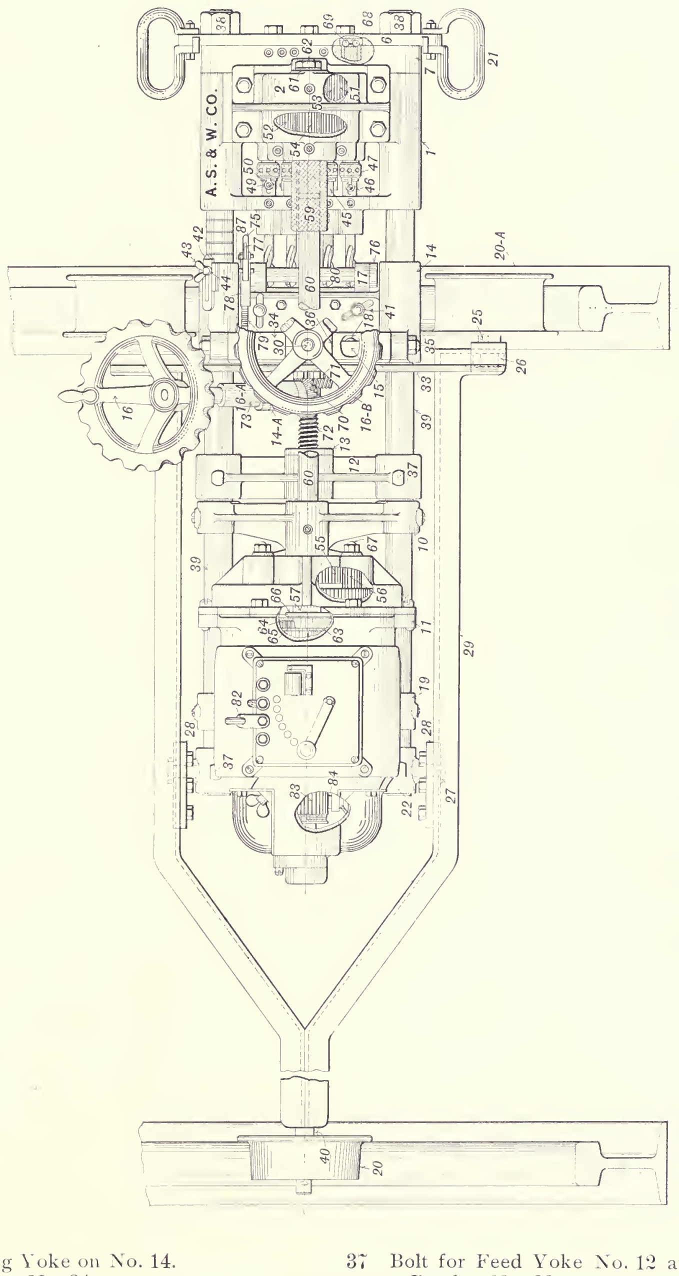
By removing a few nuts and bolts, the whole gear case can be removed from the side bars and can be replaced by a similar gear case operating a single drill spindle suitable for drilling holes of any size through webs of rails. Adjustments are provided for quickly raising or lowering the drill point for different sizes of rails. This separate attachment provides means of obtaining a first class motor driven single spindle drill, and the two styles of drills make a very flexible arrangement for any railway system using the Twin Terminal Bond as a standard.

List of Parts for Type 022 M Motor Drill

Made by American Steel & Wire Co.

1 Drill Frame.
2 Gear Housing on Drill Frame.
3 Brass Bushing in No. 2 with $1\frac{1}{8}$-inch Hole.
4 Brass Bushing in No. 2 with $\frac{13}{16}$-inch Hole.
5 Brass Bushing in No. 2 with $1\frac{1}{16}$-inch Hole.
5-A Brass Bushing in No. 2 with 1-inch Hole.
6 Thrust Plate for Drill Spindles.
7 Back Bearing Casting for Drill.
8 Brass Bushing in No. 7 with $\frac{13}{16}$-inch Hole.
9 Brass Bushing in No. 7 with $\frac{15}{16}$-inch Hole.
10 Gear Housing on Motor.
10-A Bushing in No. 10.
11 Back Bearing Cover for Motor.
12 Feed Yoke.
13 Feed Nut Bushing in Feed Yoke.
14 Feed Bracket.
14-A Bearing for No. 14.
15 Feed Points Holder.
16 Feed Wheel.
16-A Feed Wheel Shaft.
16-B Raising Wheel.
17 Bearing for Clamping Lever Stud on No. 14.
18 Screw Points on No. 15.
19 Motor Yoke.
20 Wheel on rear end of Truck.
20-A Wheel on forward end of Truck.
21 Handles on No. 6.
22 Pivot Bracket on No. 39.
23 Bushing in No. 20.
24 Bushing in No. 20-A.
25 Stud for No. 20-A.
26 Nut for No. 25.
27 Stud for No. 22.
28 Sliding Bracket.
29 Truck Frame.
30 Raising Screw.
31 Brass Washer on No. 30.
32 Nut on No. 30.
33 Yoke Bracket on Truck.

Drilling Machines



34 Raising Yoke on No. 14.
35 Stud for No. 34.
36 Nut for Raising Screw on No. 33.
37 Bolt for Feed Yoke No. 12 and Pivot Bracket No. 22.
38 Nut for No. 39.

Drilling Machines

List of Parts for Type 022 M Motor Drill—Continued

39 Guide Rods.
40 Stud for Rear Truck Wheel No. 20.
41 Adjusting Screws.
42 Drilling Gage.
43 Thumb Nut for No. 42.
44 Washer for No. 42.
45 Inside Drill Spindle and Gear.
46 Outside Drill Spindle and Gear.
47 Adjusting Nut on Drill Spindles.
49 Clamping Dog for Drills.
50 Set Screw for No. 49.
51 Intermediate Gears in No. 1.
52 40-Tooth Gear in No. 2.
53 24-Tooth Gear in No. 2.
54 Pinion Gear in No. 2.
55 55-Tooth Gear in No. 10.
56 Compound Gears in No. 10.
57 Pinion Gear on end of Armature Shaft.
58 Nut on end of No. 60.
59 Sleeve Coupling on No. 60 and No. 54.
60 Transmission Shaft between Motor and Drill.
61 Washers on end of No. 54.
62 Nut on end of No. 54.
63 Roll Bearing Bushing on end of Armature Shaft.
64 Roll Bearing Cup on end of Armature Shaft.
65 Rolls for Roll Bearing.
66 Spring Ring for No. 63.
67 Stud for Compound Gears in No. 11.
68 Ball Race in No. 6 for end of Drill Spindles.
69 3/8-inch Steel Balls for Ball Race No. 68.
70 Bevel Gear on Feed Stud No. 73.
71 Bevel Gear on Feed Screw.
72 Feed Screw.
73 Feed Stud.
74 Stud in No. 2.
75 Clamping Lever.
76 Short Clamping Lever.
77 Releasing Lever on No. 75.
78 Pawls on No. 75.
79 Pawl Rack on No. 14.
80 Lever Stud on No. 17.
81 Connecting Rod between Nos. 77 and 78.
82 Brass Connecting Post on Starting Box.
83 Armature Shaft.
84 Brush with Pig Tail.

Directions for Operating Type 022 M Motor Drill

Place machine over rails and adjust vertically for drilling by means of adjusting screw No. 41, then clamp to rail with lever No. 75.

Run drills up to rail with feed wheel No. 16 and adjust by means of adjusting nuts No. 47, so that all four drills will contact with rail. Keep all adjusting nuts No. 47 well back on spindles so as to afford good driving seats for twist drill shanks. Set depth gage No. 42 to nearest index mark on guide bars No. 39. This machine is graduated for ________ bonds.

Start motor by placing trolley terminal bushing on connecting post No. 82 and feed machine by hand, taking care that drills are cutting freely until the depth gage reaches the next index mark. Feed drills back from rail and release lever No. 75, then raise machine by means of wheel No. 16-B, so that the drill points will be above the rail when going from one joint to another. To remove twist drills from drill spindles, loosen set screw No. 43 on clamp dogs and then pull out.

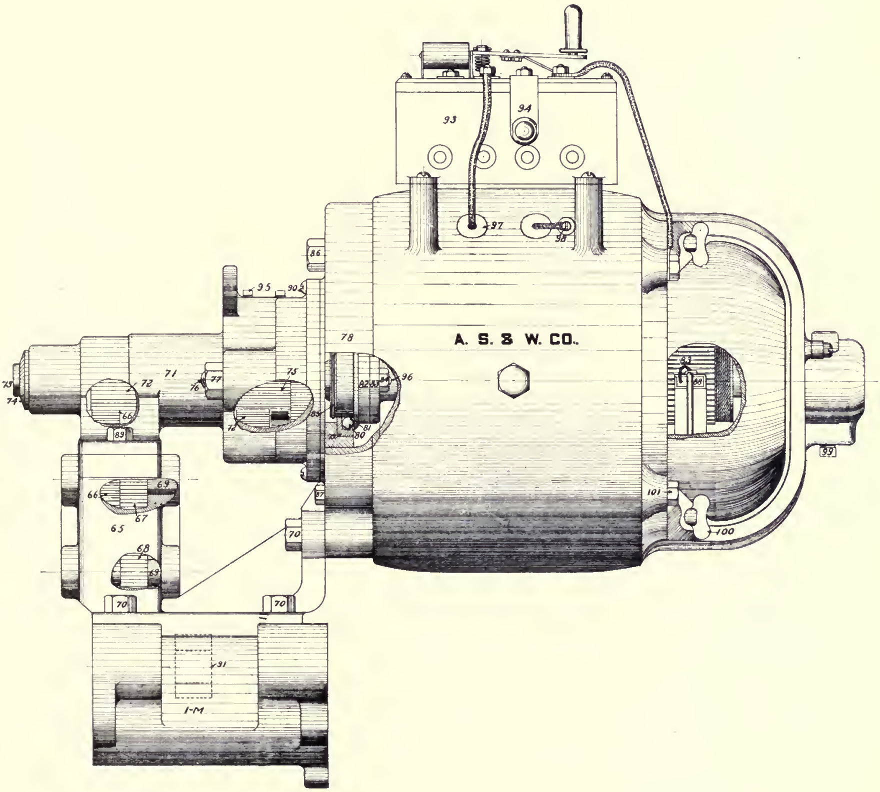
Drills must be kept sharp and ground at the correct angle at all times, duplicating the point of a new drill. Customers should use a good quality of lard oil on drill points while drilling. This is necessary to get the best results from the machine and drills, as it will prevent a lot of trouble. The holes should be cleaned with gasoline.

Keep all working parts of the machine well cleaned and oiled with a good quality machine oil, making sure that oil hole covers are always kept closed. This is very important to keep dust and sand out of bearings and will increase the life of the machine.

Motor. Use a two (2) ampere fuse wire in motor circuit at all times. Never start motor under full load. Use starting rheostat in starting motor. Keep all parts of motor wiring and especially the commutator clean and dry. Examine brushes frequently to see that they make good contact with the commutator.

Drilling Machines

(See next page)



List of Parts for Type 22 M Motor Drill

65 Motor drill casting.
66 40-tooth gear.
67 20-tooth gear.
68 30-tooth gear.
69 Stud for gears.
71 Gear housing on motor.
72 Double gear.
73 Screw on end of double gear.
75 Intermediate gears.
76 Stud for intermediate gears.
77 Nut for stud.
78 Back bearing cover.
79 Ball race for back bearing.
80 $\frac{5}{16}$-inch steel rolls.
81 Cone for ball race.
82 Pinion gear on end of armature shaft.
83 Armature shaft.
84 $\frac{5}{16}$-inch hexagon nut on armature shaft.
85 Spring on ball race cone.
87 $\frac{5}{16}$-inch cap screw on back bearing cover.
88 Carbon brush with pig tail.
90 $\frac{1}{4}$-inch round head screw on gear housing.
91 Collar to take the place of drive lever in drill.
92 Connector for joining motor with power. (Not shown.)
93 Rheostat.
94 Brass connecting post.
95 $\frac{1}{8}$-inch pipe plugs on gear housing.
96 $\frac{5}{16}$-inch stud bolt on armature shaft.
97 Insulating bushings in frame for leads.
98 Round head screw for fastening lead to body.
99 Oil drain plug.
100 Thumb screw for cover over commutator.
101 $\frac{5}{16}$-inch cap screws on front bearing yoke.

Drilling Machines

Directions for Operating Motor Drill, Type 22 M

The directions already given on page 96 for operating the type 22 double twin drill, apply equally well to the operation of type 22 M motor drill, since the drilling machines are the same in each. The rear end of this machine should be supported by blocks. After the machine has been placed in position on the rail, the motor is started by fastening the connector 92 (page 99), which is attached to the trolley wire by means of a flexible wire and light pole, to the brass connecting post 94. The motor is grounded through the drill frame to the rail.

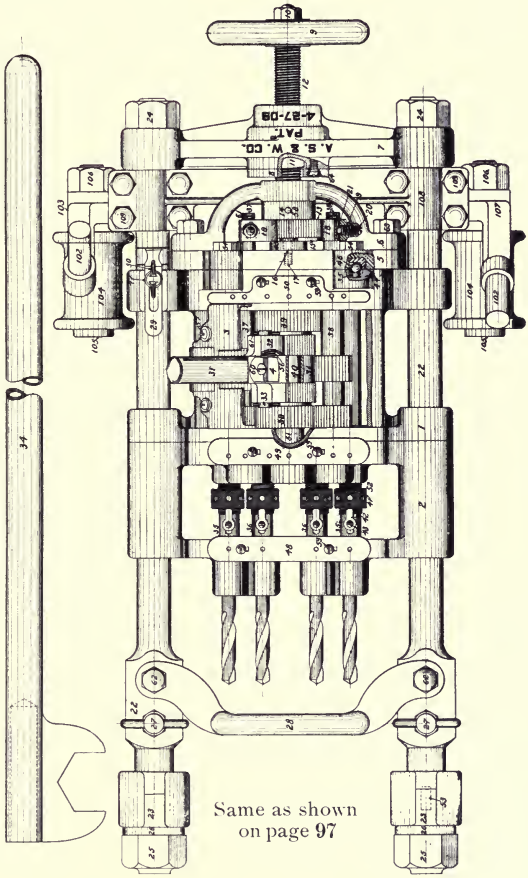
Motor Use a two (2) ampere fuse in motor circuit at all times. This should be placed on the trolley pole. Never start the motor under full load. Use the starting rheostat 93 in starting motor. Keep all parts of motor wiring, and especially the commutator, clean and dry. Examine the brushes frequently to see that they make good contact with commutator. Keep the drill points sharp and well lubricated with lard oil. The motor is built for 500-600 volts, is series wound and is amply large for the work required under normal conditions. The motor operates at variable speed, depending on load, the speed decreasing with increasing load. It should not be required to work steadily at very low voltages or under extremely heavy overloads.

Parts for Type 22 M Double Twin Drill

1 Large part of body (back).
2 Small part of body (front).
5 Truss plate on back part of body.
6 Small yoke for feed screw.
7 Large yoke for feed screw.
8 Plate on large yoke (outside of brass nut).
9 Hand wheel.
11 Brass nut on feed screw.
12 Feed screw.
13 Feed ratchet gear.
14 Collar on feed screw.
15 Cam for feed pawls on feed screw.
16 $\frac{5}{16}$-inch plunger for cam in truss plate.
17 Spring for plunger in truss plate.
18 Feed pawls.
19 Spring for feed pawl.
20 $\frac{5}{16}$-inch headless set screw in pawls.
21 Brass friction in feed pawls.
22 Guide and clamping bar for machine.
23 Loose jaw on guide bar (clamp).
24 1-inch nut on guide bar (clamp).
25 $1\frac{7}{16}$-inch nut on guide bar (clamp).
26 Washer on guide bar (clamp).
27 Adjusting screw on guide bar.
28 Tie for guide bar (clamp).
29 Depth gauge for drilling.
30 Thumb nut for depth gauge.
34 Handle and wrench for drive.
35 Single gear spindle.
36 Double gear spindle.
37 Intermediate gear.
38 Intermediate gear staggered teeth.
39 Ratchet driving gear.
40 Shaft for drive gears.
41 Adjusting nuts on spindle.
42 Clamps (dogs) for holding drills.
43 $\frac{1}{4}$-inch headless set screws.
44 Ball race in truss plate.
45 Truss block for feed screw.
46 $\frac{3}{8}$-inch balls.
48 Oil hole cover (front body).
49 Oil hole cover (back body).

Drilling Machines

(See page 98)

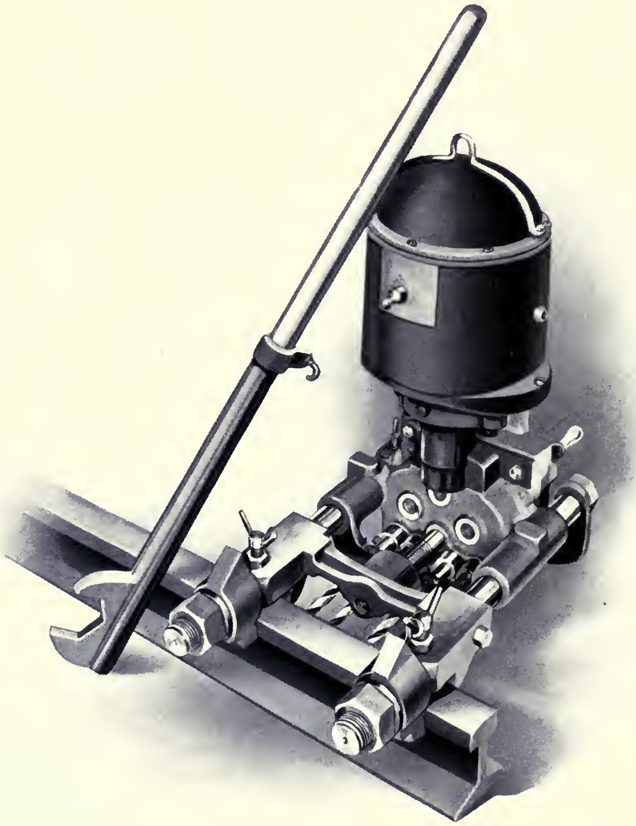


Motor Drill, Type 22 M—Continued

(Motor parts shown on page 99)

50 Oil hole cover (back body).
51 Collar on driving shaft.
52 Friction spring on adjusting nut on spindles.
53 Woodruff key for guide bars.
54 ½-inch cap screw in truss plate.
56 Spring for driving pawls.
58 $\frac{3}{16}$-inch pins for collar on feed screw.
62 ½-inch cap screws for small and large part of body truss plate and tie on guide bars.
63 ⅝-inch cap screw for small yoke.
64 $\frac{5}{16}$-inch Fil. screws for plate on large yoke outside brass nut for feed screw.
102 Handle stud.
103 Wheel bracket (right hand).
104 Wheels.
105 Wheel stud.
106 Nut for wheel stud.
107 Wheel bracket (left hand).
108 Clamping bracket.
109 ½-inch cap screws for clamping bracket.

Drilling Machines

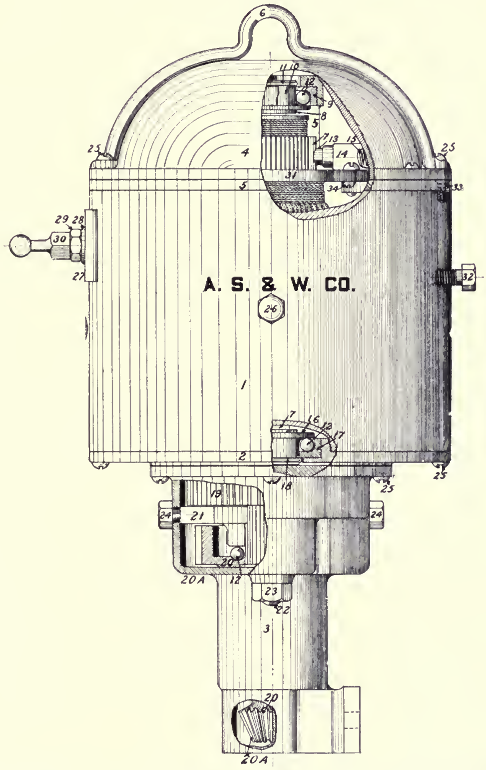


Motor Driven Drill, No. 24 M

The four-spindle motor drill shown above is one designed especially for third rail lines, and similar places where a very short and compact machine is required. It bores at one time all four holes in the head of a rail for our standard twin terminal bond. Two men can easily handle this machine and drill holes for fifteen or more joints per hour. This reduces the cost of installing the twin terminal bonds to an extremely low figure. The motor built specially for this drill is light and compact and will operate directly on a 600-volt trolley circuit. The internal windings are thoroughly protected and insulated, and the armature shaft is geared direct to the drill spindles. The machine can be carried about by using the wrench as a handle and hooking it into the motor frame. Approximate total weight, 185 pounds.

Drilling Machines

(See pages 94 and 104)



List of Parts for Type 24 M (and Type 20 M) Motor

1 Body.
2 Back bearing support.
3 Gear housing.
4 Cover over front of motor.
5 Front bearing support.
6 Brace over cover.
7 Armature shaft.
8 Bushing on armature shaft.
9 Ball race for front bearing.
10 Cone for ball bearing in front bearing.
11 Spring on cone in front bearing.
12 $\frac{5}{16}$-inch steel ball for ball bearings.
13 Carbon brush.
14 Brush holder.
15 Spring in brush holder.
16 Cone for ball bearing in back bearing.
17 Ball race for back bearing.
18 Spring on cone in back bearing.
19 Intermediate gears.
20 Double gear for type 20 motor drill.
20-A Double gear for type 24 motor drill.
21 Ball rest for truss in gear housing.
22 Stud for intermediate gears.
23 $\frac{1}{2}$-inch hexagon nut for stud.
24 Cap screw for ball rest.
26 $\frac{3}{8}$-inch cap screw on body.
27 Rubber washer.
28 Insulating bushing.
29 Hexagon nut.
30 Brass connecting post.
31 Fiber ring for brush holder.
32 $\frac{3}{8}$-inch cap screw for bracket on drill.
33 Flat head screw in body.
34 Round head screw for brush holder.
35 Connector for connecting power with post 30. Not shown.

Drilling Machines

Directions for Operating Type 24 M Motor Drill

Place clamping bars 5 over head of rail and adjust vertically for drilling by means of adjusting screws 39. Holes should be high enough on rail head to heave at least $\frac{3}{32}$-inch of steel in lower edge. Clamp machine to rail just tight enough to hold it securely, but not tight enough to break the clamping bar, with handle wrench 48 on clamping nuts 8. Machine should be level with track. Run drill points up to rail by means of crank handle 13 and adjust drills by means of adjusting nuts 36, so that all four drills will press against rails. Keep all these adjusting nuts 36 well back on spindles so as to afford good driving seats for twist drill shanks.

Set depth gauge 41 to nearest index mark on guide bars 5. Turn pawl cam 19 to mesh feed pawls 22 with feed ratchet gear 16, so that the drills will feed into rail automatically. Connect up motor and operate, drilling holes in rail to required depth, which will be shown when depth gauge travels to next index mark on guide bars. *Exact depth of holes is important.*

Lift feed pawls out of mesh with feed ratchet gear by means of pawl cam 19. Then draw back drills from rail with crank handle 13, loosen clamping nuts, remove machine from rail and move to next joint.

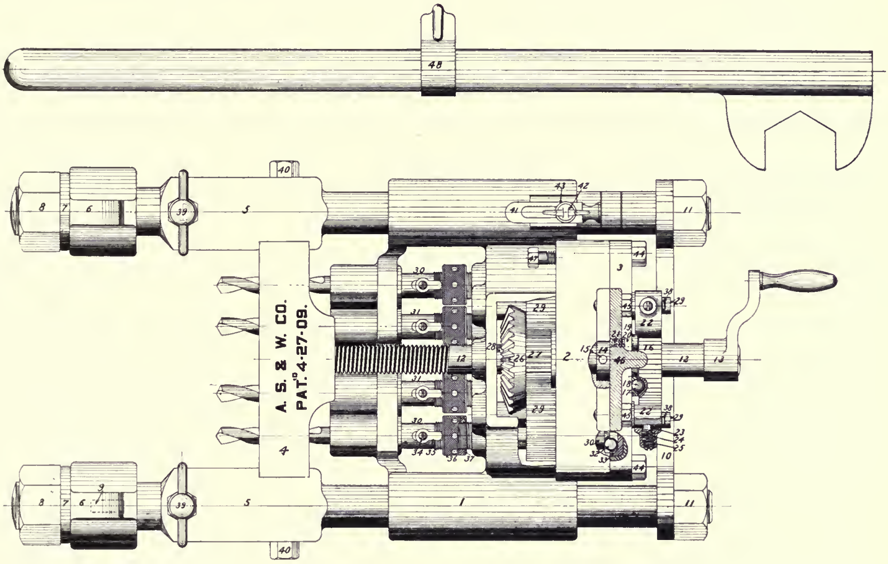
To remove twist drills from drill spindles, loosen set screw 34 on clamp dogs, then pull out of spindle end. Drills must be kept sharp and ground at proper angles at all times, else much trouble will result, and the machine may be broken. In grinding drills duplicate the exact shape of a new drill point. Keep the machine clean and free from sand.

The motor is started by fastening the connector 35 (page 103), to the brass connecting post 30 and attaching to the trolley wire by means of a flexible wire and light pole. The motor is grounded through the drill frame to the rail.

Motor Use a two (2) ampere fuse in motor circuit at all times. This can be placed on the trolley pole. Never start the motor under full load. Keep all parts of motor wiring, and especially the commutator, clean and dry. Examine the brushes frequently to see that they make good contact with commutator. Keep the drill points sharp and well lubricated with lard oil, thus avoid overloading the machine. Keep all bearings well oiled with good machine oil. The motor is built for 500-600 volts, is series wound and is amply large for the work required under normal conditions. The speed of the motor varies with and depends upon the load. It should not be required to work steadily at very low voltages, or under extremely heavy overloads.

Drilling Machines

(See page 102)

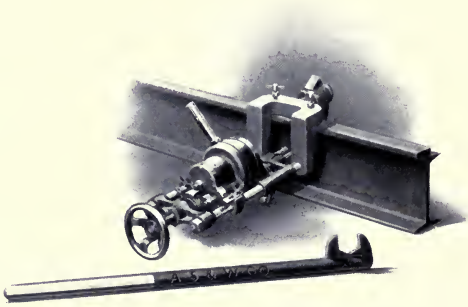


List of Parts for Type 24 M Drill

(Motor parts shown on page 103)

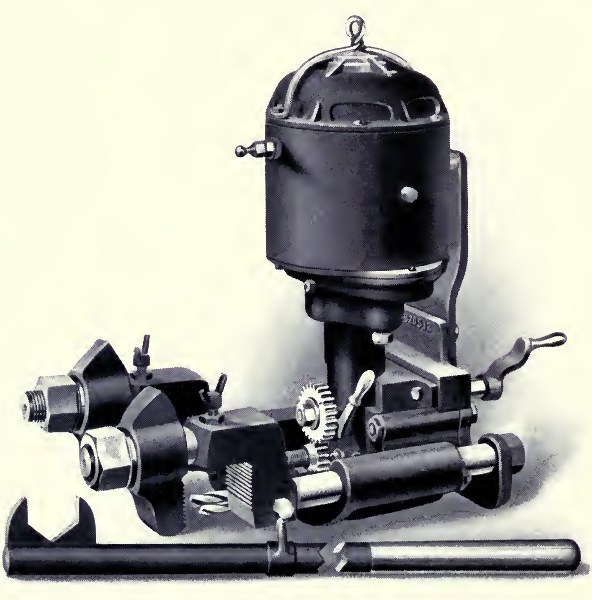
1 Large part of body (front).
2 Small part of body (back).
3 Truss plate on back part of body.
4 Yoke for feed screw.
5 Guide and clamping bar for machine.
6 Loose jaw on guide bars (clamp).
7 Washer on guide bars (clamp).
8 $1\frac{7}{16}$-inch nut on guide bars (clamp).
9 Key for guide bars.
10 Yoke strap on guide bars.
11 1-inch nut on guide bars.
12 Feed screw.
13 Crank handle.
14 Collar on feed screw.
15 Pin in collar on feed screw.
16 Feed ratchet gear.
17 Ball race in truss plate for feed screw.
18 $\frac{3}{8}$-inch steel balls.
19 Cam for feed pawls.
20 Plunger in truss plate for feed pawls.
21 Spring in truss plate for plunger.
22 Feed pawls.
23 Brass plunger for friction in feed pawls.
24 Spring for feed pawls.
25 $\frac{5}{16}$-inch headless set screw for feed pawls.
26 Bevel gear for connecting drill with motor.
27 Spur gear on bevel gear.
28 Stud for spur and bevel gear.
29 Intermediate gears.
30 Drill spindles with gear, $2\frac{5}{8}$ inches from outer edge of thread.
31 Drill spindles with gear, $3\frac{3}{8}$ inches from outer edge of thread.
32 $\frac{3}{8}$-inch steel balls.
33 Ball race in truss plate.
34 $\frac{1}{4}$-inch headless set screw for dogs on spindle.
35 Clamps (dogs) for holding drill.
36 Adjusting nut on drill spindle.
37 Friction spring on adjusting nut on spindle.
39 Adjusting screw on guide bars.
41 Depth gauge for drilling.
42 Thumb nut for depth gauge.
44 $\frac{1}{2}$-inch cap screws on truss plate.
45 $\frac{3}{8}$-inch cap screws on bracket.
46 Bracket to support motor on drill.
47 $\frac{3}{8}$-inch cap screw for fastening motor to drill.
48 Handle and wrench for machine.

Drilling Machines



Two-spindle Drill, Type No. 20, for Soldered Stud Bonds

The two drills shown on this page have been developed primarily for the installation of type B. S. B. bonds on webs of rails, though they can be used equally well for drilling holes in the heads of rails for twin terminal bonds. These are two-spindle machines, drilling two half-inch holes 1¼-inch centers in one operation. No. 20 is operated by hand, and weighs approximately 80 pounds. No. 20 M is operated by a 600-volt series wound motor and weighs approximately 105 pounds. Special brackets for connecting to head of rail will be made for either drill, adapting either for drilling holes in web or head of any style or size of rail. The same high class of material and workmanship enters into the construction of these drills as in the four-spindle drills already described.



Motor Drill, Type No. 20 M

Drilling Machines

Directions for Operating Type 20 and Type 20 M Drills

Place clamping bars over head of rail and adjust vertically for correct position of holes in rail, as shown on opposite page. Clamp machine to rail tight enough to hold it securely, but not tight enough to break the clamping bar, with handle wrench on clamping nuts. Machine should be level with track. Run drill points up to rail by means of hand wheel or crank handle and adjust drills by means of adjusting nuts, so that both drills will press against rails. Keep all the adjusting nuts well back on spindles so as to afford good driving seats for drill shanks.

For twin terminal bonds set depth gauge to nearest index mark on guide bars and turn pawl cam to mesh feed pawls with feed ratchet gear, so that the drills will feed into rail automatically. Place handle wrench on driving stud or connect up motor and operate, drilling holes through the rail web or to required depth in the head.

Lift feed pawls out of mesh with feed ratchet gear by means of pawl cam. Then draw back drills from rail with hand wheel or crank handle, loosen clamping nuts, remove machine from rail, move to next joint, and repeat.

To remove twist drills from drill spindles, loosen set screw on clamp dogs, then pull out of spindle end. Drills must be kept sharp and ground at proper angles at all times, else trouble will result, and the machine may be broken. In grinding drills duplicate the exact shape of a new drill point. Keep the machine clean and free from sand.

The motor is started by fastening the brass connecting post with connector, which is attached to the trolley wire by means of a flexible wire and light pole. The motor is grounded through the drill frame to the rail.

Motor Use a two (2) ampere fuse in motor circuit at all times. This should be placed on the trolley pole. Never start the motor under full load. Keep the drill points sharp and well lubricated with lard oil and thus avoid overloading the machine. Keep all bearings well oiled with good machine oil. The motor is built for 500-600 volts, is series wound and is amply large for the work required under normal conditions. Speed of motor varies with and depends upon the load. It should not be required to work steadily at very low voltages, or under heavy overloads.

See pages 108 to 111.

Drilling Machines

List of Parts for Type 20 Hand Drill

(See page 106)

1 Large part of body (back).
2 Small part of body (front).
3 Truss plate on back part of body.
4 Clamping frame.
5 Clamp bar.
6 Loose jaw on clamp bar.
7 Loose washers on clamp bar.
8 $1\frac{7}{16}$-inch nut on clamp bar.
9 Key on clamp bar.
10 Guide rods.
11 Yoke for feed screw.
12 Nuts on guide rods.
13 Small yoke on feed screw.
14 Feed screw.
15 Hand wheel.
16 Pin in hand wheel.
17 Collar on feed screw.
18 Pin in collar on feed screw.
19 Truss block for feed screw.
20 Feed ratchet gear.
21 Spring for plunger in truss plate.
22 Plunger for cam in truss plate.
23 Feed pawls.
24 Cam for feed pawls.
25 Brass plunger for friction in feed pawls.
26 Springs for feed pawls.
27 $\frac{5}{16}$-inch headless set screw for feed pawls.
28 Drive lever for driving machine.
29 Pawls for drive lever.
30 Double ratchet driving gears.
31 Single ratchet driving gear.
32 Stud for drive lever (pawl stud).
34 Intermediate gear with the gears $1\frac{15}{16}$ inches apart.
35 Intermediate gear with the gears $\frac{7}{8}$ inch apart.
36 Drill spindle with one gear.
37 Drill spindle with two gears.
38 $\frac{1}{4}$-inch headless set screw for dogs on spindle.
39 Clamp (dogs) for holding drill.
40 Adjusting nuts on spindles.
41 Friction spring on adjusting nuts on spindles.
42 $\frac{3}{8}$-inch steel balls.
43 Ball race.
44 Clamping screw on clamp bar.
45 Adjusting screws on clamp bar.
46 Depth gauge for drilling.
48 Thumb nut for depth gauge.
50 Dust shield on drive lever.
51 Cap screw for small yoke in truss plate.
52 Cap screw for truss plate.
53 Cap screw for small and large part of body.
54 Handle and wrench for drive.

List of Parts for Type 20 M Drill

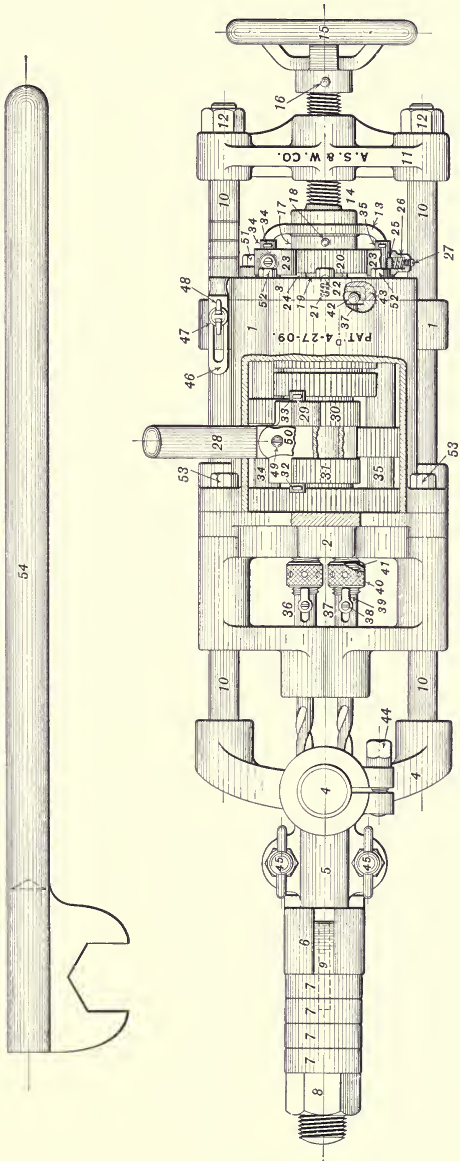
Lists of parts of motor shown on page 111

(See page 106)

1 Large part of body (front).
2 Small part of body (back).
3 Truss plate.
4 Yoke for feed screw.
5 Guide and clamping bar for machine.
6 Loose jaw on guide bar (clamp).
7 Loose washer on guide bar (clamp).
8 $1\frac{7}{16}$-inch nut on guide bars (clamp).
9 Key in guide bars.
10 Yoke strap on guide bars.
11 1-inch nut on guide bars.
12 Feed screw.
13 Feed ratchet gear.
14 Ball race for feed screw in body.
15 $\frac{5}{16}$-inch steel balls.
16 Cam for feed pawls.

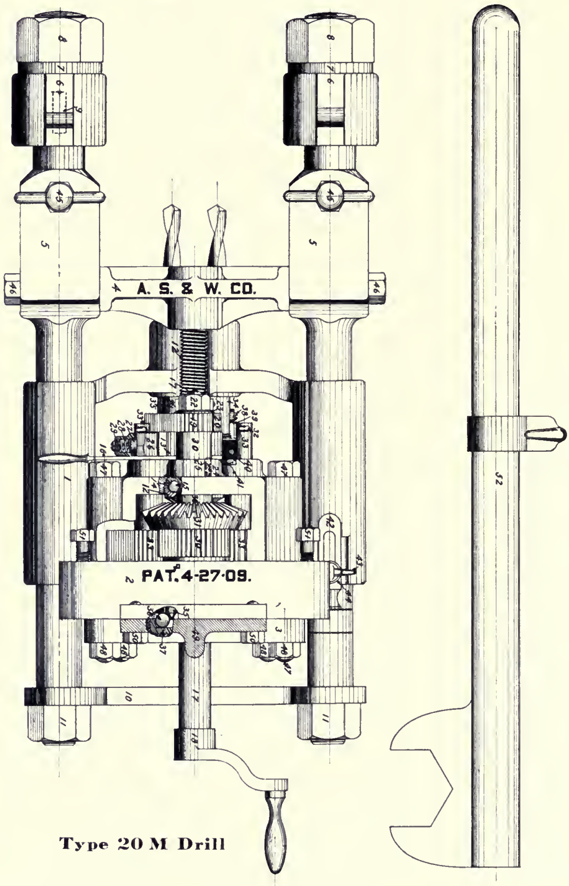
(Parts continued on page 110)

Drilling Machines



Type 20 Hand Drill

Drilling Machines



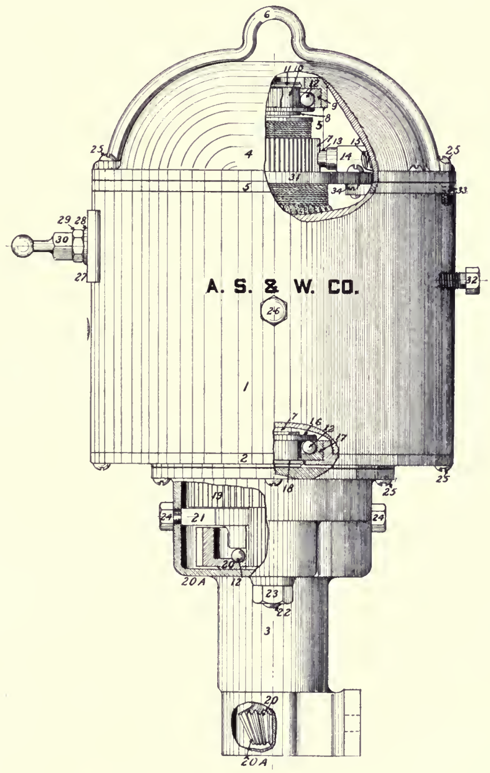
Type 20 M Drill

(List of parts continued from page 108)

17 Stud for reversing feed.
18 Crank handle.
19 Gear on reversing stud.
20 Gear on feed screw.
21 Pin in gear on feed screw.
22 Nut on stud for reversing feed.
23 Washer on stud for reversing feed.
24 Spring for plunger in body.
25 Plunger for feed cam in body.
26 Feed pawls.
27 Brass plunger for friction in feed pawls.
28 Spring in feed pawls.
29 $\frac{5}{16}$-inch headless set screw in feed pawls.
30 Drive gear.
31 Bevel gear on drive gear stud to connect drill with motor.
33 Intermediate gears.
34 Drill spindle with gear 2⅝-inch from outer edge of thread.
35 Drill spindle with gear 3⅜-inch from outer edge of thread.
36 ⅜-inch steel balls.
37 Ball race in truss plate.
38 ¼-inch headless set screw for dogs in spindle.
39 Clamps (dog) for holding drill.
40 Adjusting nut on drill spindle.
41 Friction spring on adjusting nut on spindle.
42 Depth gauge for drilling.
43 Thumb nut for depth gauge.
45 Adjusting screw on guide bars.
47 ½-inch bolts for fastening parts of drill together.
49 Bracket to support motor on drill.
50 ⅜-inch cap screw on bracket.
51 ⅜-inch cap screw for fastening motor to body of drill.
52 Handle and wrench for machine.

Drilling Machines

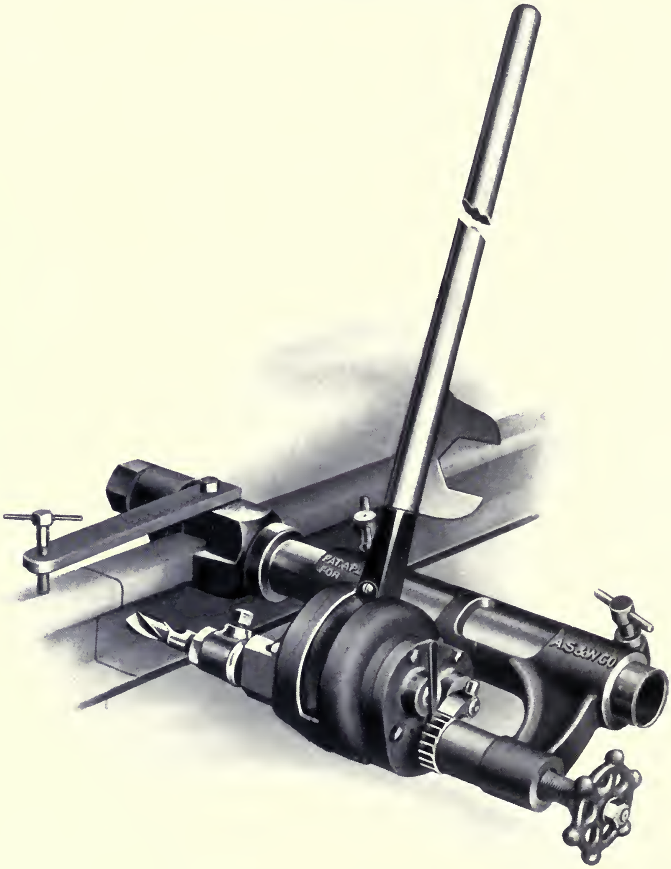
(See page 106)



List of Parts for Type 20 M Motor

1 Body.
2 Back bearing support.
3 Gear housing.
4 Cover over front of motor.
5 Front bearing support.
6 Brace over cover.
7 Armature shaft.
8 Bushing on armature shaft.
9 Ball race for front bearing.
10 Cone for ball bearing in front bearing.
11 Spring on cone in front bearing.
12 $\frac{5}{16}$-inch steel ball for ball bearings.
13 Carbon brush.
14 Brush holder.
15 Spring in brush holder.
16 Cone for ball bearing in back bearing.
17 Ball race for back bearing.
18 Spring on cone in back bearing.
19 Intermediate gears.
20 Double gear for type 20 motor drill.
20A Double gear for type 20 motor drill.
21 Ball rest for truss in gear housing.
22 Stud for intermediate gears.
23 ½-inch hexagon nut for stud.
24 Cap screw for ball rest.
26 ⅜-inch cap screw on body.
27 Rubber washer.
28 Insulating bushing.
29 Hexagon nut.
30 Brass connecting post.
31 Fiber ring for brush holder.
32 ⅜-inch cap screw for bracket on drill.
33 Flat head screw in body.
34 Round head screw for brush holder.
35 Clamp for connecting power with post 30. Not shown.

Drilling Machines



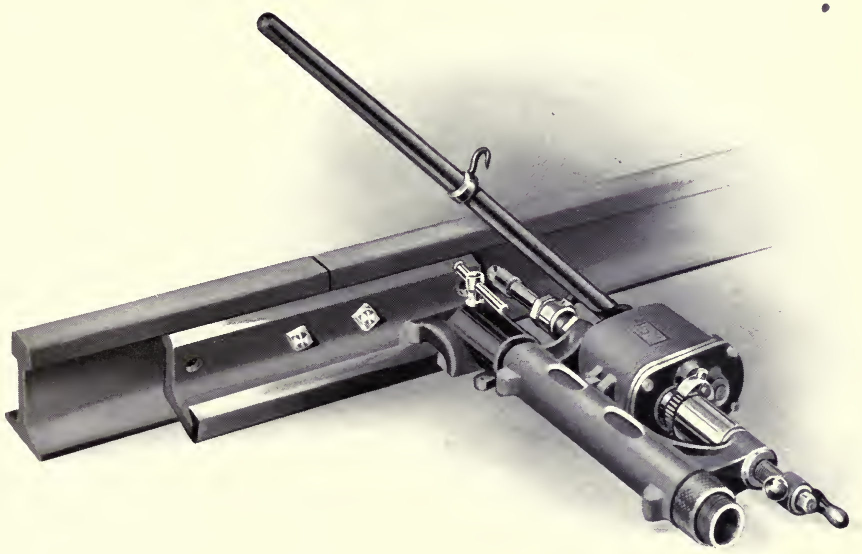
Single Spindle Drill No. 21

(See page 114)

The large single spindle drills shown on this and the next page will bore any size hole up to 1⅛ inch, through rail webs for any type of single stud terminal bond. Like the multiple spindle drills already described, they have a double acting lever and an automatic feed. They are adjustable in all respects and are provided with fittings for rigid attachment to the rail, either by means of a special splice bar, as shown in No. 021, or to the head of the rail, as shown in No. 21. Being held so rigidly, the drill points will pass entirely through the rail without breaking, at the same time boring a perfectly smooth and true hole. These drills have many distinct advantages over other track drills, as pointed out on page 94.

Type No. 21 can be used on all roads where traffic will permit. It has a positive and simple method of attachment to the head of the rail. Approximate weight, 85 pounds.

Drilling Machines



No. 021 Drill
(See pages 116 and 117)

Type No. 021 has been developed specially for drilling rails on roads where traffic cannot be interrupted. The drill is attached to a special splice bar made for each style of rail. This special bar is provided with a guide along the lower edge of its base to which the drill may be rigidly attached, and along which it can easily be moved and set for each bond hole. The special bar replaces one of the regular plates and is held in position by two track bolts. Two of these special bars accompany each drill, so that as the holes are being drilled at one joint, the plates can be changed at the next joint by another operator. This whole drilling outfit lies below the top of the rails, thus allowing trains to pass above it freely. This makes an ideal drill for use by electrified steam roads, where it is unsafe to attach any device to the head of the rail. It cannot be used on T-rails under 85 pounds per yard in size.

Nos. 21 and 021 drills can readily be operated by two men who should drill from twelve to fifteen holes per hour, depending upon the rail and traffic conditions.

Approximate weight of No. 021 drill, 100 pounds, and of the plate, 40 pounds.

Drilling Machines

Directions for Operating Type 21 Drill

Place clamp bar 4 over ball of rail and clamp securely, but not enough to break the rod, using handle wrench 54 on clamping nut 6. Bring adjusting screw 31 into contact with top of rail. Run back drill spindle 20 by means of crank handle 30 to within one-eighth inch of brass bushing 14. Loosen clamp screws 28 and adjust frame 1 so that drill point will be in required position for drilling, and as close to the rail as possible, then tighten screws 28 firmly. Turn pawl cam 27 to mesh feed pawls 26 with feed ratchet on feed sleeve 8. Place driving handle wrench 54 on driving lever 9 and operate drill.

Allow the feed of the machine to drive the drill entirely through the rail. If fed through by hand after the point has passed partly through, it is liable to leave a burr in the hole, and injure the bond terminal when installed. Take pawls out of mesh with feed ratchet by means of pawl cam 27, after hole is drilled. Draw drill spindle and drill back by means of crank handle 30.

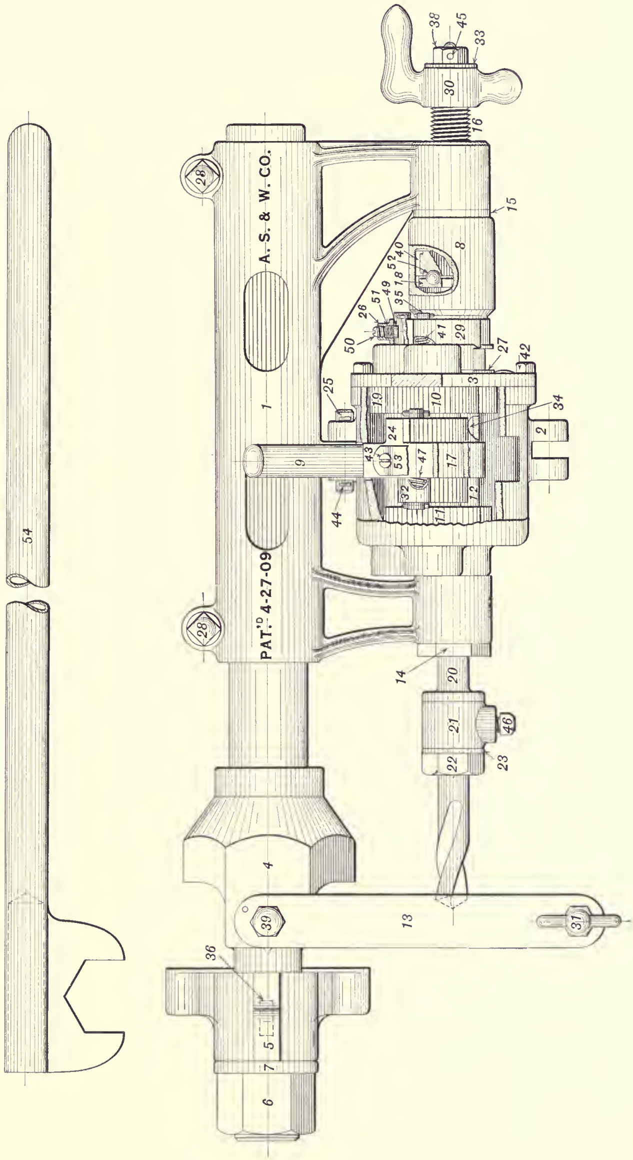
Drill must be kept sharp and ground to the proper angle at all times. This is very important. Oil on the drill point is optional with the customer, but the life of machines and drills is prolonged, and the machine works much easier when good lard oil is used. The holes can be cleaned with gasoline.

List of Parts for Type 21 Drill

1 Frame.
2 Body.
3 Cover on body.
4 Clamp bar.
5 Loose jaw on clamp bar.
6 Nut on clamp bar.
7 Washer on clamp bar.
8 Feed sleeve.
9 Driving lever.
10 Ratchet driving gear—25 teeth.
11 Ratchet driving gear—27 teeth.
12 Gear sleeve on drill spindle.
13 Adjusting bar on clamp bar.
14 Brass bushing in front end of frame.
15 Brass bushing in rear end of frame.
16 Feed screw.
17 Shaft for driving lever and gears.
18 Ball race on drill spindle.
19 Intermediate gear.
20 Drill spindle.
21 Collar on drill spindle.
22 Large nut on drill spindle.
23 Large washer on drill spindle.
24 Stud for driving pawls.
25 Stud for connecting body to frame.
26 Feed pawl.
27 Cam for feed pawls.
28 Clamp screws on frame.
29 Catch pawl for feed ratchet.
30 Crank handle on feed screw.
31 Adjusting screw.
32 Driving pawls.
33 Washers on rear end of drill spindle.
34 Key in drill spindle.
35 Stud for catch pawl.
36 Key in clamp bar.
38 Small nut on drill spindle.
39 Cap screw for adjusting bar.
40 Key in feed screw.
41 Spring for catch pawl.
42 Cap screws for body.
43 Round head screw for driving lever.
46 Set screw for clamping drill in spindle.
47 Spring for driving pawls.
49 Friction plunger in feed pawl.
50 Headless set screw in feed pawl.
51 Spring in feed pawl.
52 3/8-inch steel balls (ball bearing).
53 Shield (gear cover).
54 Driving handle and wrench.

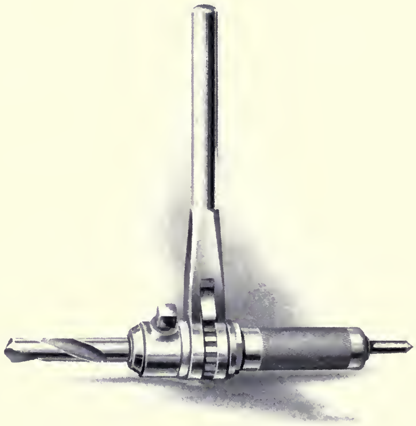
Drilling Machines

(See page 112)



Type 21 Drill

Drilling Machines



Ratchet Drill No. 19

The above ratchet drill under some conditions can be used to very good advantage, and for that reason we are making the one shown above. This drill is of our own make and will do its work well.

Directions for Operating Type 021 Single Spindle Drill

Fasten splice bar 5 to rail with two track bolts and place clamping bracket 4 of machine over splice bar. Locate machine for drilling by letting drilling gauge drop in hole in splice bar. Then clamp machine to splice bar by means of screw 7.

Adjust drill point vertically by means of screw 56 and clamp rear end of frame 1 to clamping bracket 4 by means of lever 51, making sure that frame presses against nuts 53.

Place wrench 55 on driving shaft 18 and adjust cam 34 to place feed pawl 39 into mesh with feed ratchet and sleeve 42, then operate drill.

When hole is drilled, take feed pawl out of mesh and draw drill back out of hole by means of handle 48.

Release clamping lever 51 and turn machine over on clamping bracket, to drill hole for other end of bond.

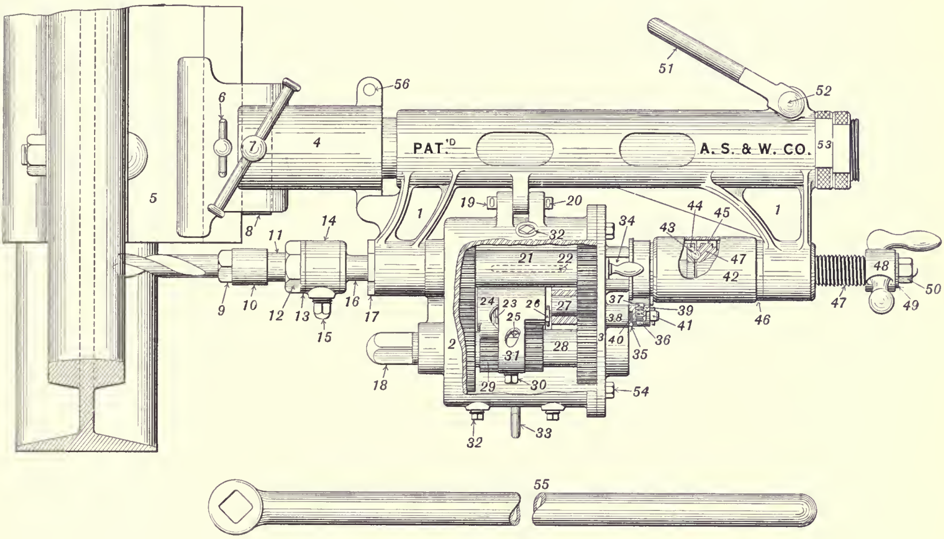
To clamp drill in holder, insert drill into holder 11 and tighten nut 9.

To take drill out of holder, place wrench on nut 9 and 12 and loosen nut 9.

Drills must be kept sharp, and ground at the proper angle at all times. Oil on drill points is optional with customers. The life of the machine and drill is much prolonged when lard oil is used and the machine works much easier.

Drilling Machines

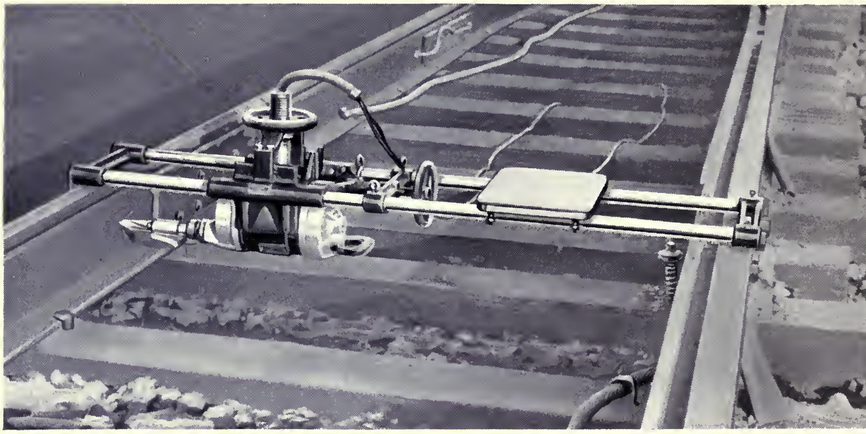
(See page 113)



List of Parts for Type 021 Single Spindle Drill

1 Frame.
2 Gear case.
3 Cover on gear case.
4 Clamping bracket.
5 Special splice bar.
6 Drilling gauge.
7 Clamping screw.
8 Clamping gibb.
9 Nut on drill holder.
10 Bushing on drill holder.
11 Drill holder.
12 Large nut on drill spindle.
13 Large washer on drill spindle.
14 Set screw holder on drill spindle.
15 Set screw on holder.
16 Drill spindle.
17 Brass bushing in frame.
18 Driving shaft in gear case.
19 Pin for holding frame and gear case.
20 Dowel pin on frame and pawl pin.
21 Double gear in gear case.
22 Key in drill spindle for double gear.
23 Spring in driving pawl.
24 Driving pawls.
25 Key in driving shaft.
26 Stud for driving pawls.
27 Intermediate gear in gear case.
28 Driving ratchet and gear (28-tooth gear).
29 Driving ratchet and gear (34-tooth gear).
30 Set screw in pawl holder.
31 Pawl holder.
32 ¼-inch pipe plug.
33 Hook on gear case.
34 Feed pawl cam.
35 Take-up pawl.
36 Headless set screw in feed pawl.
37 Friction plunger in feed pawl.
38 Spring in feed pawl.
39 Feed pawl.
40 Spring in take-up pawl.
41 Stud for take-up pawl.
42 Feed ratchet and sleeve.
43 ⅜-inch steel ball in feed sleeve.
44 Ball race on drill spindle.
45 Key on feed screw.
46 Feed nut in frame.
47 Feed screw.
48 Handle on feed screw.
49 Small washer on drill spindle.
50 Small nut on drill spindle.
51 Clamping lever on frame.
52 Bolt on clamping nut.
53 Nuts on clamping brackets.
54 Cap screw on gear case cover.
55 Wrench for machine.
56 Adjusting set screw, for drilling.

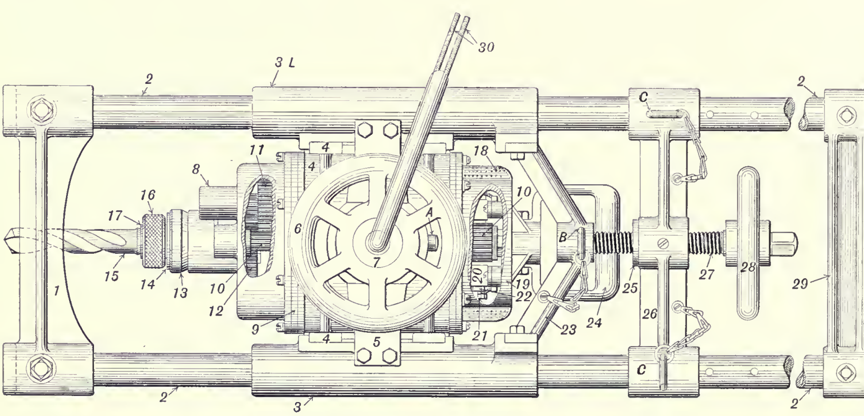
Drilling Machines



Motor Drill, Type 21 M

(Duntley Track Drill)

The above cut represents the most recent type of heavy duty single spindle motor drill. It is mounted in a special frame and forms the most complete and convenient motor track drill on the market. The side spindle feature of the drill permits drilling close to the ties without the use of an angle gear, and the vertical screw adjustment affords ready means of locating the holes vertically on ordinary T- or deep girder rails. The horizontal rods are of seamless drawn tubing and the bearing surface of the drill frame on the rods is very long, insuring true, straight holes so essential for efficient bonding. A screw and band wheel feed is provided in the combination with means for quickly removing the drilling tool for sharpening or renewal. Weight of track drilling frame complete with electric drill, 150 pounds.



Drilling Machines

Directions for Operating Type 21 M Drill

Place machine over the rails with the ears on the under part of yoke, 1 resting on the outside of rail. If on a steep grade, clamp frame to rails with cam 31.

To adjust for drilling, turn hand wheel 6 on bracket 7 to raise or lower the drill until the right position has been found.

Bring drill point up to rail and put end of feed screw 27 into thrust yoke 23 and put pin "B" in to hold screw. Now adjust yoke 26 and drop pins "C" through holes in yoke and guide rods.

Start motor by means of switch button "A."

When hole is drilled, take pins "B" and "C" out and bring back yoke 26, then pull machine back by means of handle 24.

Drills must be kept sharp and ground at the proper angles at all times. Oil on drill points is optional with customers. The life of machine and drill is much prolonged when lard oil is used. The holes can be cleaned with gasoline. Special high speed drills should be used in this machine. See page 140.

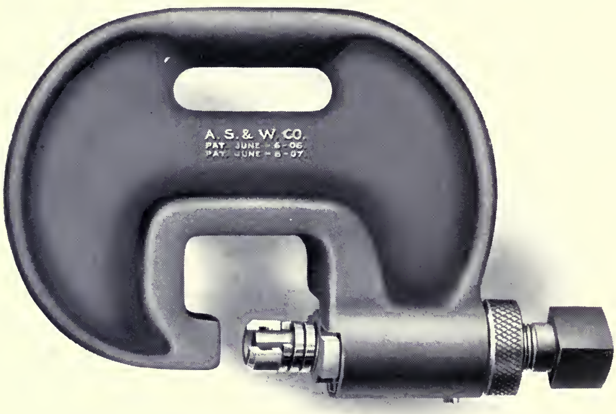
Motor Use a two (2) ampere fuse in motor circuit at all times. This should be placed on the trolley pole. Never start the motor under full load. Keep the drill points sharp and well lubricated with lard oil and thus avoid overloading the machine. Keep all bearings well oiled with good machine oil. The motor is built for 500–600 volts, is series wound and is amply large for the work required under normal conditions. It should not be required to work steadily at very low voltages, or under heavy overloads.

List of Parts for Type 21 M Motor Drill

1 Yoke on guide rods on front of machine.
2 Guide rods.
3 Slide bracket on guide bar (right hand).
3–L Slide bracket on guide bar (left hand).
4 Motor frame.
5 Yoke on motor frame for adjusting.
6 Adjusting wheel on yoke.
7 Adjusting bracket on motor frame.
8 Gear housing on motor frame.
9 Cover between gear housing and frame.
10 Armature shaft, pinion and commutator.
11 Intermediate gears in housing.
12 Gear on drill spindle.
13 Sleeve outside of drill spindle.
14 Drill spindle.
15 High speed drill with No. 3 Morse shank.
16 Knurled nut on drill spindle.
17 Sleeve in drill spindle.
18 Cover on bearing casting.
19 Bearing casting.
20 Brush holder.
21 Spring for brushes.
22 Carbon brushes.
23 Thruss yoke.
24 Handle on bearing casting.
25 Feed nut.
26 Yoke for feed nut.
27 Feed screw.
28 Hand wheel on feed screw.
29 Yoke on guide rods on rear end of machine.
30 Lead wires for motor.
31 Cam for clamping frame to rail not shown.

Compressors

In these screw compressors, the old style outer screw has been replaced by a cylindrical sleeve 2, which in one position is free to slide in or out of the frame with a single thrust or pull of the operator. Turning this sleeve through a quarter revolution brings two shoulders to press against the compressor frame, and these take all the thrust of the inner screw ram. This construction is similar to the breech block of a modern cannon. The speed with which it can be operated gives to this tool a distinct advantage over the large outer screw of the older style compressors. This mechanism also permits the use of a short stiff well constructed screw ram, and brings the wrench close to the frame of the tool and near to the rail. These features add to the life and effectiveness of the tool.



No. 40-48 Screw Compressor

To bring the head or crown of the terminal against the web of the rail, a steel collar 5, backed by a strong compression spring 7, is placed around and projects beyond the ram toward the web of the rail. When the breech block is thrown forward and the ram is screwed in, the collar which surrounds the projecting end of the terminal stud will be pressed against the web of the rail with great force by the compression spring, thereby drawing the head of the terminal into place against the other side of the rail.

The diameter of the collar 5 is slightly greater than the diameter of the hole in the rail. As the terminal stud expands and forms the button in front of the ram, the flow of the copper over the rail surface is restricted to the diameter of the collar, so that the metal of the stud is kept directly in front of the ram, where it should be in order to produce a very intense contact pressure.

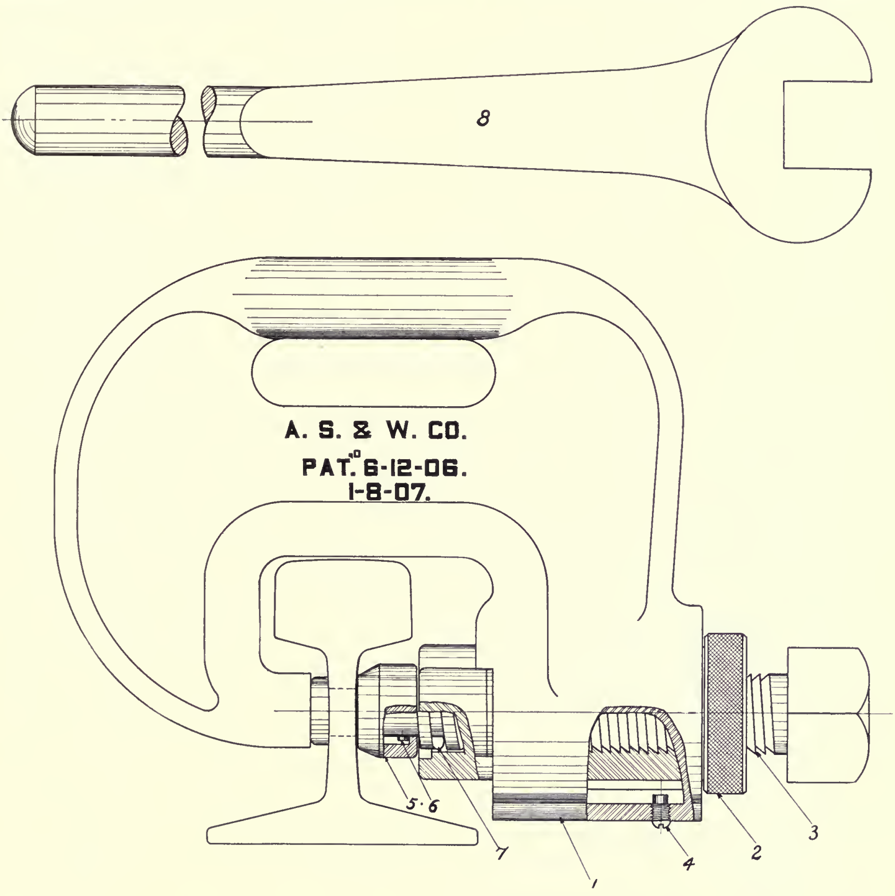
The frame is of high grade cast steel and it is compact, strong and durable, and the compressor produces uniformly good results. The strength of each frame is ample to sustain the load for compressing 1 inch diameter terminals, or less, with a good margin of safety.

We make five styles of screw compressors, which differ only in form and size of frame.

Compressors

Hand Screw Compressors

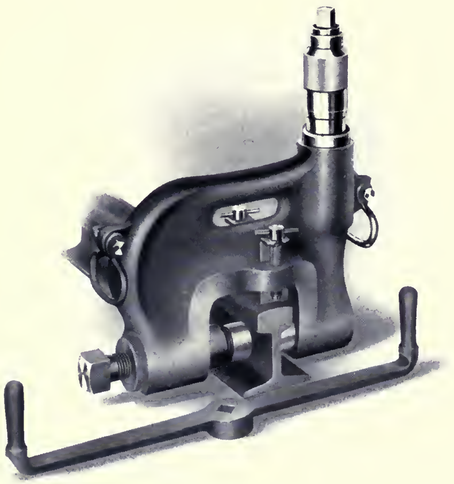
Number of Compressor	Approximate Weight, Pounds	Style and Size of Rail
40	67	T-rails up to 5¼ inches
42	80	T-rails under 7 inches
44	105	Girder rails under 7 inches
46	140	Girder rails up to 9 inches
48	165	Girder rails 9 inches and over



List of Parts for Type 40-48 Screw Compressor

1 Body casting.
2 Breech block sleeve.
3 Screw ram.
4 Screw in body.
5 Collar on screw ram.
6 $\frac{3}{16}$-inch pin in screw ram.
7 Spring on screw ram.
8 Wrench for machine.

Compressors



Type 61 Hydraulic Screw Compressor

The screw hydraulic compressor, shown above, is built upon entirely new principles. It is extremely strong and durable, rapid in action and contains no valves or intricate parts to get out of order. It has a capacity of 35 tons, which pressure exerted on a terminal stud will produce lasting and effective results, as explained on page 15.

Weight, 115 pounds.

Directions for Operating Type 61 Screw Hydraulic Compressor

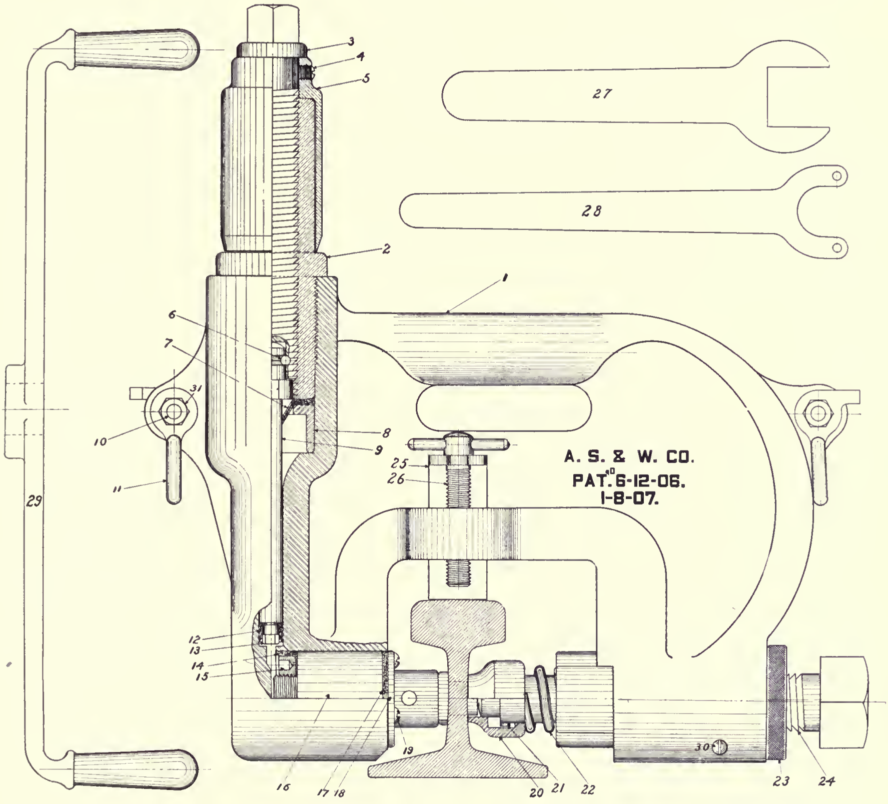
Run the piston screw 3 up until the outer sleeve 5 is at the top of the threaded sleeve 2. Then run screw 24 clear back and draw out the steel breech block sleeve 23 as far as necessary to place the compressor over the ball of the rail. By means of adjusting screws 26 adjust the machine vertically to allow the collar 20 to pass over the projecting end of the bond terminal, and then return sleeve 23 to its proper place and turn shoulders against the stops provided. Tighten the screw ram 24 very solid against rail over terminal with wrench 27. Make sure that the oil chamber is properly filled with machine oil. By turning the outer sleeve 5 by hand, the piston should be felt to strike the oil when the outer sleeve is half an inch down on the threaded brass sleeve 2.

By means of wrench 29, run the piston screw 3 down to the bottom or shoulder of the threaded sleeve 2. The terminal of the bond will then have been fully and effectively compressed. Now run the piston screw back to the top of the threaded sleeve 2, and the screw ram 24 back to its original place. Draw back the sleeve 23, lift compressor from the rail, and all is ready for the next terminal.

Bond terminals should be straight, smooth and clean. No bond terminal or bond hole should vary enough in diameter to require more than one compression. Our bond terminals are within .005 inch of specified size, and our No. 21 drilling machines will drill holes within this same limit.

These standard machines have ample factors of safety in all cases when the bond terminals and the holes they are intented to fit are of correct size. A machine with extra heavy frame will be furnished at slightly increased cost for extra special compression work.

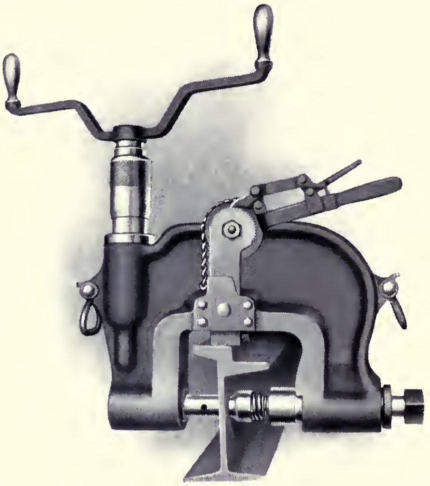
Compressors



List of Parts for Type 61 Screw Hydraulic Compressor

1 Body or frame.
2 Threaded brass sleeve.
3 Piston screw.
4 $\frac{5}{16}$-inch headless cap screw for outer sleeve.
5 Outer sleeve.
6 ¼-inch pin in piston screw and on small piston.
7 Leather packing for cup in oil chamber.
8 Steel cup for oil chamber.
9 Small piston.
11 Handles on body.
12 Leather cup packing on end of small piston.
13 Packing screw on end of small piston.
14 Leather cup packing on large piston.
15 Brass nut on large piston.
16 Large compressor piston.
17 Leather washer on large piston.
18 Brass washer on large piston.
19 ¼-inch round head screw on large piston.
20 Collar on screw ram.
21 ¼-inch pin in screw ram.
22 Spring on screw ram.
23 Breech block sleeve.
24 Screw ram.
25 Adjusting gauge.
26 Adjusting screw.
27 Wrench for sleeve screw.
28 Spanner wrench for nut on large piston.
29 Wrench handle.
30 ½-inch headless set screw in body.

Compressors



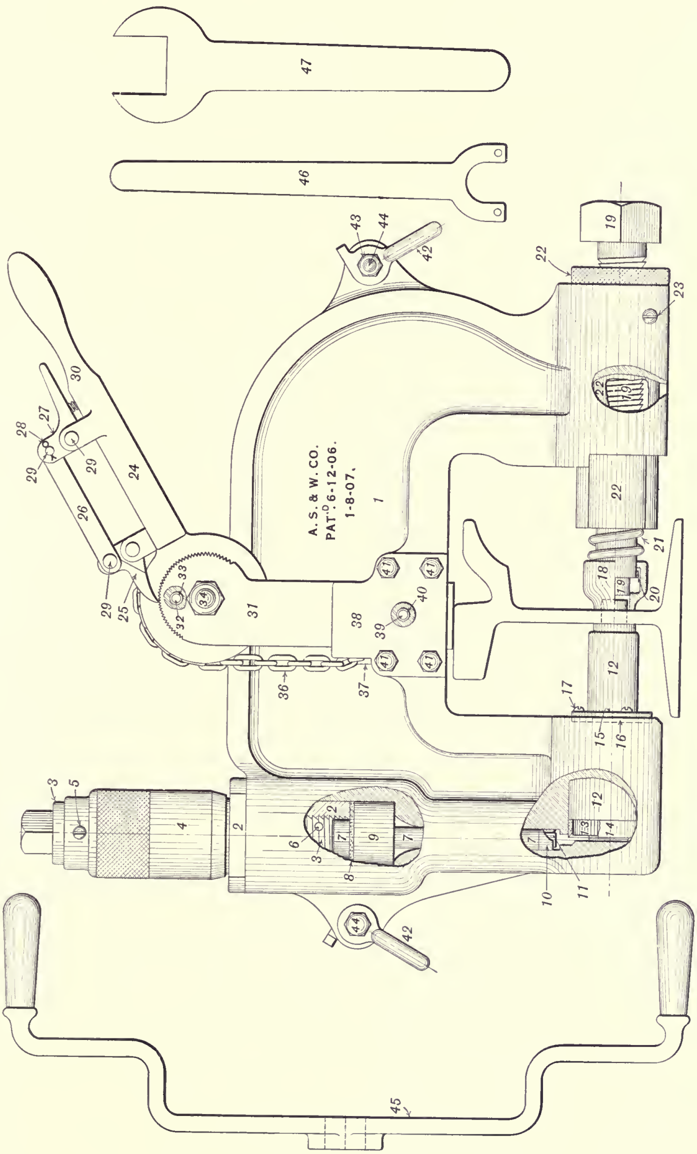
063 and 064 Screw Hydraulic Compressors

The screw hydraulic compressor shown above is a special and heavier form of No. 61 compressor already described on preceding page, and is made for use on large rail sections. The No. 063 compressor, which weighs 160 pounds complete, will work on all girder and high T-rails under seven inches in height, while No. 064 compressor, weighing 180 pounds, is intended for all rails equal to and over seven inches in height. These machines are operated just the same as No. 61 compressor, directions for which have already been given.

List of Parts for Type 063 and 064 Compressor

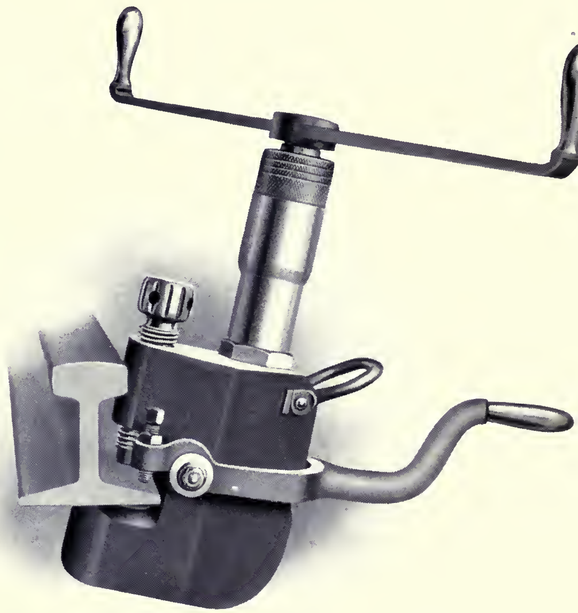
1 Body.
2 Threaded brass sleeve.
3 Piston screw.
4 Outer sleeve.
5 $\frac{5}{16}$-inch headless set screw in outer sleeve.
6 ¼-inch pin in piston screw and on small piston.
7 Small piston.
8 Leather packing for oil chamber cup.
9 Oil cup for oil chamber.
10 Cup packing for end of small piston.
11 Packing screw in end of small piston.
12 Large compressor piston.
13 Brass nut on large piston.
14 Leather cup packing on large piston.
15 Brass washer on large piston.
16 Leather washer on large piston.
17 ¼-inch round head screw on large piston.
18 Cup on sleeve screw.
19 Sleeve screw.
20 ¼-inch pin in sleeve screw.
21 Spring on sleeve screw.
22 Steel sleeve.
23 ½-inch headless set screw in body.
24 Lever for adjusting shoe.
25 Pawl for locking shoe.
26 Link for connecting pawl with handle.
27 Handle for releasing pawl.
28 Cotter pin for pins in pawl on handle.
29 Pins for pawl on handle.
30 Spring in lever.
31 Adjusting shoe.
32 Plunger in shoe.
33 Spring for plunger in shoe.
35 Nut for stud.
36 Chain for connecting lever with body.
37 Hook for chain.
38 Plate on body over shoe.
39 Plunger in plate.
40 Spring for plunger in plate.
42 Handles on body.
45 Wrench handle for piston screw.
46 Spanner wrench for nut on large piston.
47 Wrench for screw in steel sleeve.

Compressors



063 and 064 Screw Hydraulic Compressors

Compressors



Screw Hydraulic Compressor No. 68

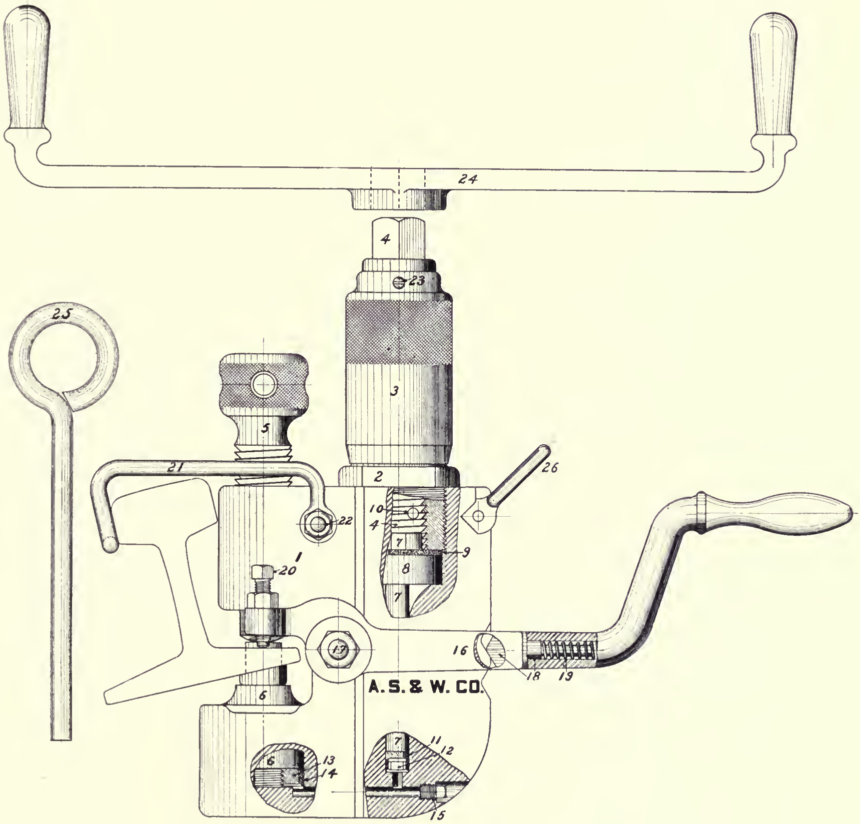
This represents a very compact and light but powerful and effective form of screw hydraulic compressor for installing type U. S.-B. rail bonds (see page 92) in the flange of T-rails. It is a companion tool to the hydraulic punch No. 66, shown on succeeding page. All metal parts are of steel and well constructed. Weight, 60 pounds.

Directions for Operating Type 68 Screw Hydraulic Compressor

Run the piston screw 4 up until the outer sleeve 3 is at the top of the threaded sleeve 2. Turn back screw ram 5 far enough to pass over bond terminal projecting through rail base. Place compressor on rail, bring point of ram 5 over center of terminal and place hook 21 over ball of rail. Set lever 16 by means of adjusting screw 20, so that when handle of lever is drawn upward the terminal head will be drawn up against base of rail. Run ram 5 solid against bond terminal by means of rod 25. Make sure that oil chamber is properly filled with oil. By means of wrench 24, now run the piston screw 4 down as far as it will go, or until the outer sleeve 3 contacts with bottom of threaded sleeve 2. The bond terminal will then be fully and effectively compressed.

Run the piston screw back to the top of the threaded sleeve 2, and the ram 5 back to its original place, move compressor to next terminal and repeat.

Compressors

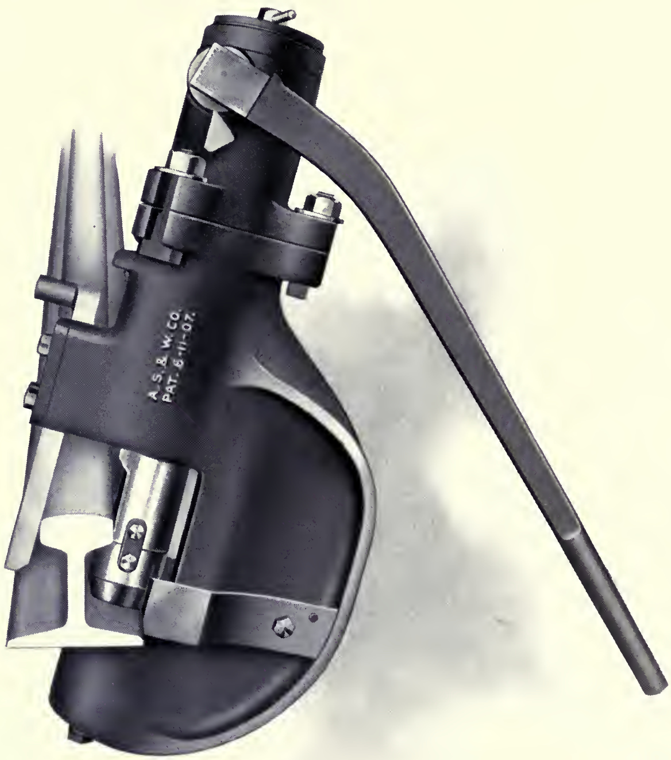


List of Parts for Type 68 Screw Hydraulic Compressor

(Patents pending)

1 Body.
2 Brass threaded sleeve.
3 Outer sleeve.
4 Piston screw.
5 Screw ram.
6 Large compressor piston.
7 Small piston.
8 Steel cup for oil chamber.
9 Leather packing for cup in oil chamber.
10 ¼-inch pin in piston screw and on small piston.
11 Leather cup packing on end of small piston.
12 Packing screw in end of small piston.
13 Brass nut on end of large piston.
14 Leather cup packing for large piston.
15 ⅛-inch pipe plug in body.
16 Lever for forcing rail on head of bond.
18 Plunger in lever.
19 Spring for plunger in lever.
20 Adjusting screw on lever.
21 Hook for holding machine to rail.
23 Headless set screw in outer sleeve.
24 Wrench handle.
25 Rod for large screw in body.
26 Handle on body.

Compressors



Hydraulic Punch No. 66

This is a very effective and highly developed machine for punching one inch holes or smaller through the flange of T-rails for type U. S.–B. rail bonds. It is a companion tool to the screw hydraulic compressor No. 68, described on preceding page. It is provided with a pump having two pistons, one of large diameter for filling the power cylinder quickly, and one of small diameter for applying the working pressure. The pump and power piston are above the rail, bringing a minimum amount of metal below the rail. A knuckle joint between the die and the plunger ram permits the die to readily adjust itself to any irregularities in the rail section. The frame is made of high grade cast steel and is strong and durable. Weight of machine complete, 200 pounds.

Compressors

Directions for Operating Type 66 Hydraulic Punch

Place machine on rail with edge of flange resting against guide strap 56, and lower the slide 48 over head of rail. Release all the valves by forcing down operating levers 4 and 5 against ears on body of pump. Make sure that pump is properly filled with clean oil, which should reach within ½ inch of the top of pump. Insert lever 59 in operating lever 5 and work large piston until punch 54 and die 53 are tight on the rail. Insert lever 59 in operating lever 4 and work small piston until hole is punched in rail.

Release valves and insert end of lever 59 in slot of slide 48, and by prying under ball of rail force back punch 54 from hole in rail, then pull slide up and remove machine from rail. To carry this punch, insert lever 59 in opening back of 39, and use lever as handle or use small handle 41.

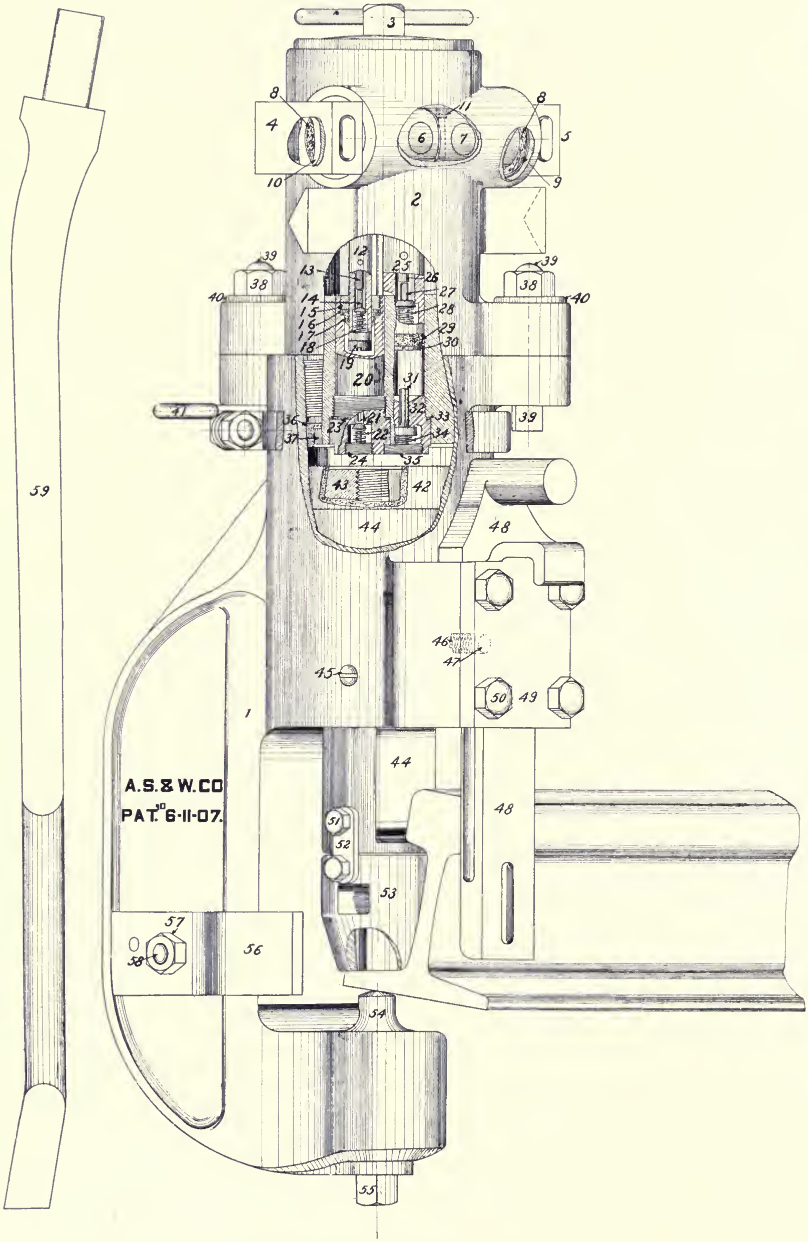
CAUTION—Make sure that punching or slug is *removed* from the die 53, after each hole is punched. Keep all inner working parts clean and nicely adjusted.

List of Parts for Type 66 Hydraulic Punch

(Diagram of punch shown on page 128)

1 Body of punch.
2 Body of pump.
3 Cover on pump.
4 Operating lever for high pressure piston.
5 Operating lever for low pressure piston.
6 Piston and releasing lever for high pressure piston.
7 Piston and releasing lever for low pressure piston.
8 Leather washers on operating lever.
9 Threaded washer, right hand thread.
10 Threaded washer, left hand thread.
11 Screw and pin for releasing levers.
12 High pressure piston.
13 Rod in high pressure piston.
14 Valve stem in high pressure piston.
15 Stuffing nut in valve chamber.
16 Leather washer for stuffing nut.
17 Cup packing for stuffing nut.
18 Spring for valve in high pressure piston.
19 Plug on end of high pressure piston.
20 Valve chamber for high pressure piston.
21 Valve in valve chamber.
22 Spring for valve in valve chamber.
23 Leather washer on valve chamber.
24 Nut in end of valve chamber.
25 Low pressure piston.
26 Rod in low pressure piston.
27 Valve stem in low pressure piston.
28 Spring for valve in low pressure piston.
29 Leather cup packing in end of low pressure piston.
30 Nut in end of low pressure piston.
31 Valve stem.
32 Valve chamber for low pressure piston.
33 Leather washer for valve chamber.
34 Spring for valve in valve chamber.
35 Nut on valve chamber.
36 Cup packing on end of pump.
37 Nut for packing on end of pump.
39 Bolt for fastening pump and punch.
40 Washer for bolt fastening pump and punch.
41 Handle for machine.
42 Leather cup packing on end of large piston.
43 Brass nut on end of large piston.
44 Large compression piston.
45 Headless set screw in body for large piston.
46 Spring in body for plunger for slide.
47 Plunger for slide.
48 Slide.
49 Plate for slide.
52 Connecting link.
53 Die.
54 Punch.
55 Screw for punch.
56 Guide strap.
59 Lever for pump.

Compressors

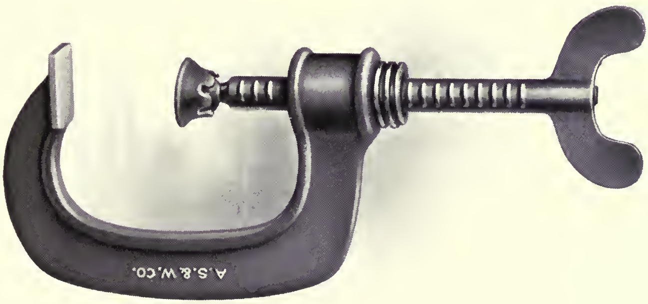


Type 66 Hydraulic Punch

(See preceding page)

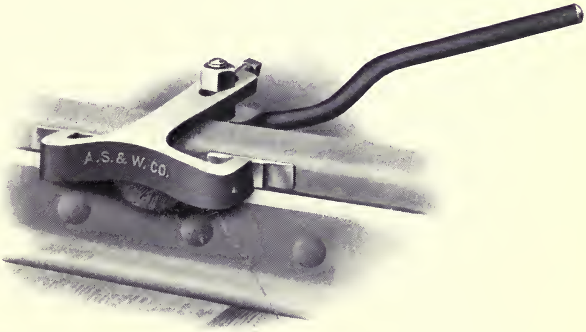
Tools for Soldering

Material Needed for Soldered Bonds



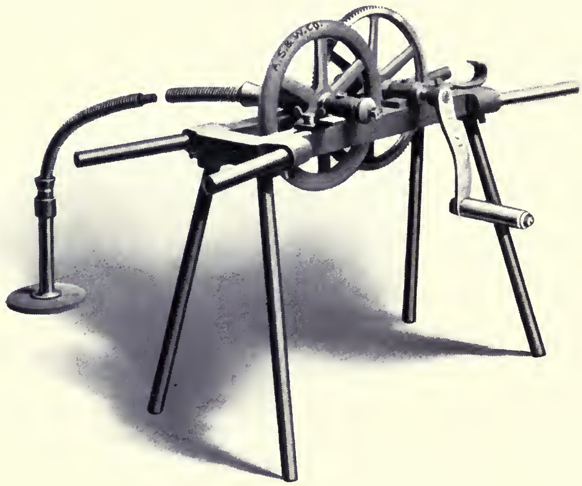
Clamp No. 84 for all Types of Soldered Bonds

Clamps The operation of the clamps for holding soldered bonds in position while soldering is a detail of considerable importance. The effectiveness and economy of our clamps are unequalled. They are very simple, strong and durable, and can be manipulated easily to locate and hold the bond securely while soldering.



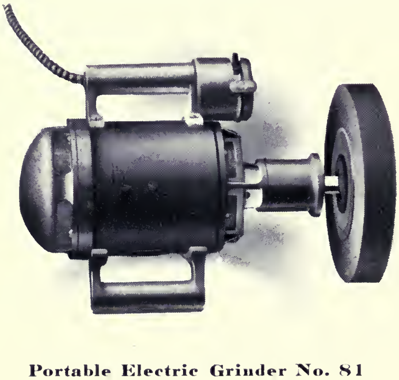
Clamp No. 85 for Form 1 Soldered Bonds

Tools for Soldering



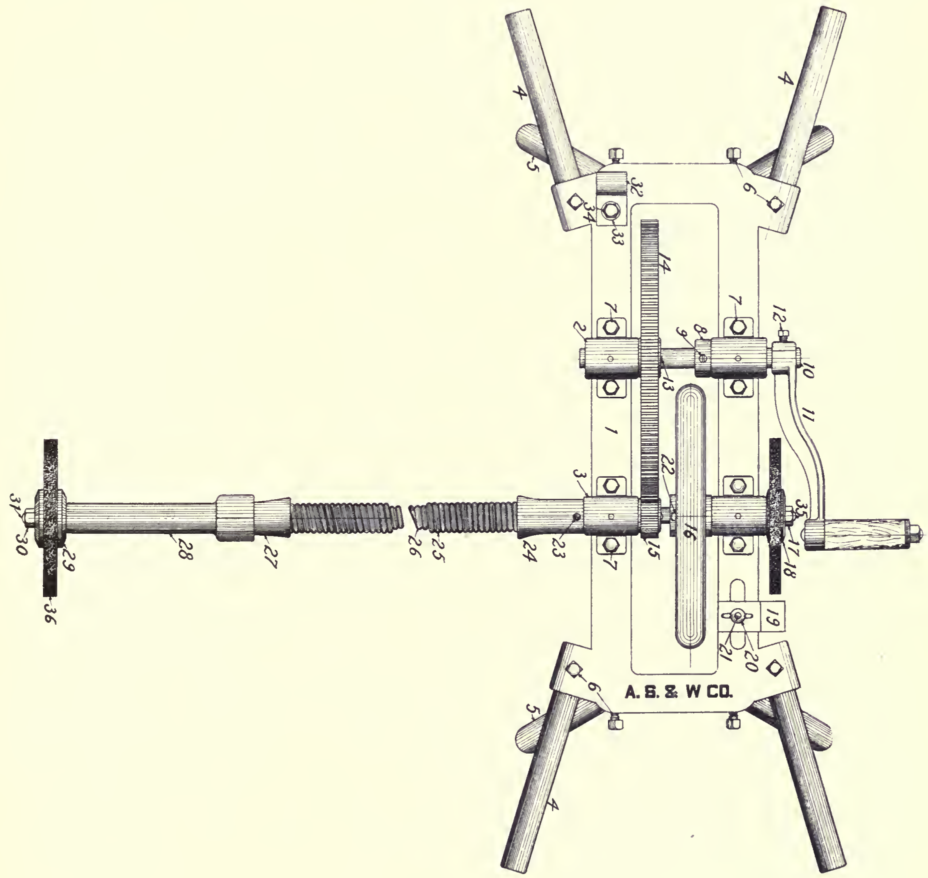
Hand-power Grinder No. 80

Hand-power Grinding Machine The frame of the hand-power grinding machine is made of cast steel. All wearing parts are machined accurately to size. The shaft is our special design, made of the highest grade of tempered spring steel and is very flexible. This machine, though light and easily handled, will endure very rough usage.



Portable Electric Grinder No. 81 (Duntley)

Portable Electric Grinder We illustrate here a very convenient outfit for grinding rail surfaces when electric power is available. A small six hundred volt D. C. motor with rheostat and switch attached to the handle has the emery wheel mounted directly on the armature shaft, as shown. Total weight, 30 pounds; speed, 2400 revolutions per minute. A two-ampere fuse should be placed in the motor circuit.



List of Parts for No. 80 Hand-power Grinder

1 Frame.
2 Bearing for driving shaft.
3 Bearing for high speed shaft.
4 Handles.
5 Pipe legs.
8 Collar on driving shaft.
9 Set screws in collar on driving shaft.
10 Driving shaft.
11 Crank handle.
13 Keys for gears.
14 Large gear.
15 Pinion gear.
16 Balance wheel.
17 Nut on high speed shaft.
18 Collar for emery wheel on high speed shaft.
19 Grinding rest.
20 Thumb nut.
21 Bolt for grinding rest.
22 Set screw in balance wheel.
23 Set screw in sleeve on flexible shaft.
24 Sleeve on flexible shaft.
25 Outer spring for flexible shaft.
26 Inner spring for flexible shaft.
27 Sleeve on spindle end of flexible shaft.
28 Sleeve for emery wheel spindle on flexible shaft.
29 Collar for emery wheel on spindle.
30 Nut on wheel spindle.
31 Emery wheel spindle.
32 Catch for flexible shaft.
33 Washer on catch for flexible shaft.
34 Cap screw on catch for flexible shaft.
35 High speed shaft on machine.
36 Emery wheel.

Tools for Soldering

Double Burner Brazier No. 83 for Soldered Bonds

Braziers The brazier is a most potent factor in the cost of installing soldered bonds. Our type has two adjustable burners, which consume all of the generating gases and produce an intense flame, which is regulated by needle valves in each burner, or by a single globe valve in the swinging arm. By means of a pipe wrench, the burners are placed in the position most advantageous for any given type of bond. The tank holds enough fuel to last more than half a day, and is equipped with a very efficient air pump, the handle of which serves for carrying the tank. All parts of this brazier are simple in design, strong and durable.

List of Parts for Type 83 Double Burner Brazier

1 Gasoline tank.
2 Pump handle and rod.
3 Pump rod guide.
4 Leather washer for pump rod guide.
5 Brass plug in cup in top of tank.
6 Brass cup on top of tank.
7 Leather washer in cup on top of tank.
8 Pump tubing.
9 Large steel washer on pump rod.
10 Leather cup packing for pump.
11 Small steel washer on pump rod.
12 ¼-inch hexagon nut on end of pump rod.
13 Air valve seat.
14 Leather plug in air valve.
15 Air valve in pump chamber.
16 Spring in air valve.
17 Leather washer for brass plug in lower end of tank.
18 Brass plug in lower end of tank.
19 Brass elbow union.
20 Union nut.
21 Brass nipple in union.
22 Air valve chamber in pump.
23 Elbow pipe.
24 ⅜-inch x 1⅝-inch nipple between valve and lower elbow.
25 ⅜-inch globe valve.
26 ⅜-inch pipe between globe valve on tee pipe.
27 Tee pipe.
28 ⅜-inch x 3¾-inch pipe nipple between tee and elbow.
29 Hook for holding pipes up.
30 Burner.
31 Shield on burner.
32 ¼-inch round head screw for shield on burner.
33 Needle valve seat nut on burner.
34 Stuffing nut on burner.
35 Needle valve stem.
36 $\frac{5}{16}$-inch x 1¼-inch set screw on burner.
37 $\frac{5}{16}$-inch x ½-inch set screw on burner.
38 ⅜-inch x ½-inch set screw on burner.
39 ⅜-inch x 3-inch pipe between elbow and burner.

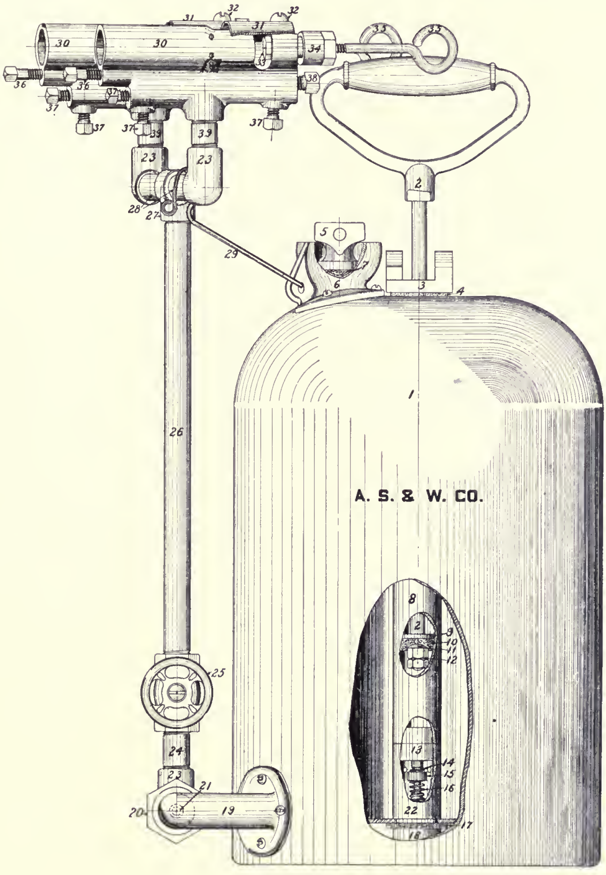
Tools for Soldering

Directions for Operating Type 83 Double Burner Brazier

To start the torch, remove brass plug 5, and pour a good grade of clean gasoline into tank, leaving 2-inch top space for air. Pump air into tank by means of pump handle 2. Quite high pressure required for best results.

Lower burners 30 from tank, letting them rest on rail or a stone. Open globe valve 25 and needle valves 35, and light escaping gasoline, regulating valves 35, so that not too much gasoline escapes. When burners get heated and give out blue flame, they will be ready for work.

Burners 30 should be turned or adjusted so that flame will strike squarely on surface to be heated. Adjust screws 36 so as to bring hottest portion of flame against rail surface. When through brazing, close valves 35 and globe valve 25 and let air out of tank by means of brass plug 5.



Brazier Torch Type 83

Rail Bond Testers

Directions for Using A. S. & W. Rail Bond Tester

(See page 41)

Place the two-point contact bar 1 across the rail joint, bringing the contact points 4 into contact with the inner or bright edge of rail head. Ordinarily these points should be 12 inches apart for correct readings, though they may be spaced nearer together for short bonds. A very slight pressure on the hand lever 12 will be sufficient to make positive contacts with the rail provided the points are kept sharp.

The single-point contact bar 22 carrying the tape-line 27 should be placed on the rail, either to the right or to the left of the joint, according to direction it is intended to work, and if let fall an inch or so on top of the rail, the contact will be good. Connect the single-point contact bar 28 with instrument binding post marked R (rail), and hook tape line on nearest end of two-point contact bar. Always connect the two contact points above the rail joint to the instrument so that the center instrument binding post marked C will be connected with the central or common contact point on the rail, or the one nearest to the single-point contact bar.

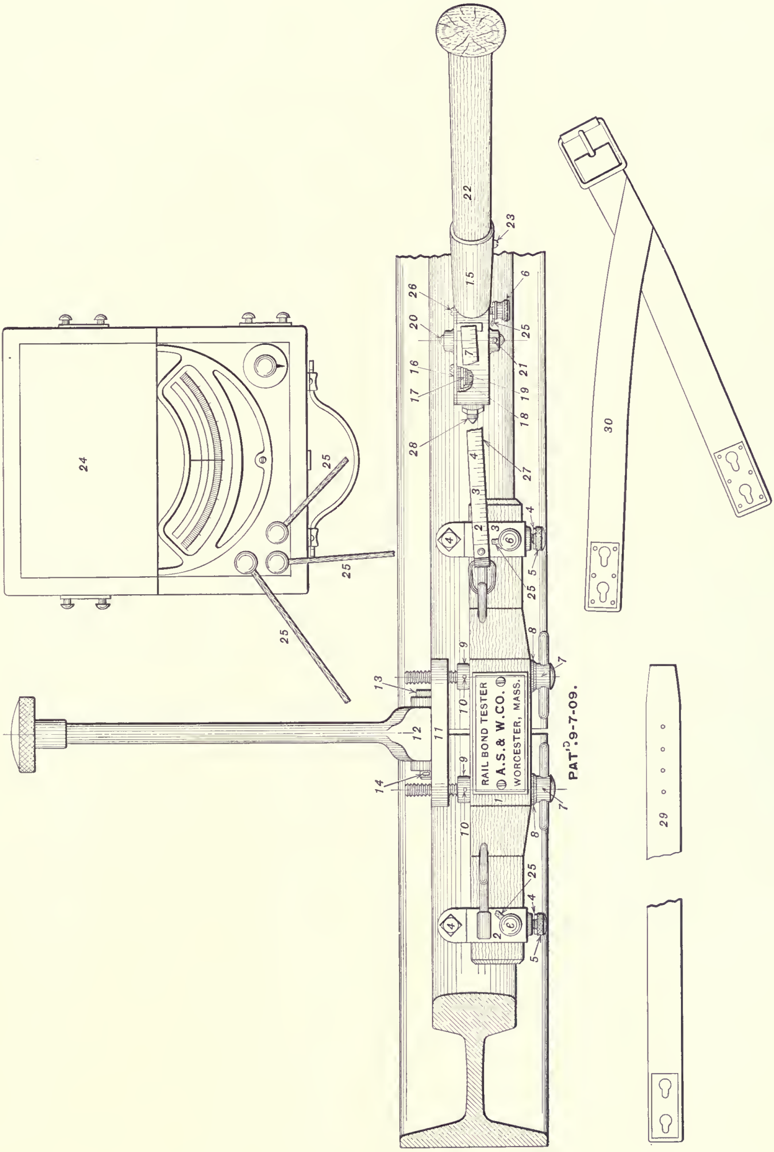
By means of the shoulder-strap 30 suspend the instrument in a horizontal position, so that on open circuit the needle rests on zero. The millivoltmeter is differentially wound, and the right-hand scale measures the potential drop across the joint. In this circuit is placed an open circuit (O. C.) switch, and a multiplier of 10, marked 250, which should be used in every case where there is liable to be a sharp deflection.

Handle the instrument carefully on account of its delicate construction. The needle is adjustable to zero by screw on box cover. When everything is in readiness, as above outlined, and when there is sufficient direct current flowing through the rail for a readable deflection, move the single-point contact bar out on the uncut rail until zero deflection is obtained, when the number of feet of rail equivalent in resistance to the joint is read off the tape-line direct.

List of Parts for A. S. & W. Rail Bond Tester

1 Contact bar.
2 Right hand contact post.
3 Left hand contact post.
4 Contact screws.
5 Clamping screws on contact posts.
6 Binding screws on contact posts.
7 Adjusting screws.
8 Washers on adjusting screws.
9 Collar on adjusting screws.
10 Pin in collar on adjusting screws.
11 Adjusting bar.
12 Hand lever.
13 Stud on adjusting bar.
14 Cotter pin for stud on adjusting bar.
15 Tape holder.
16 Cover for tape holder.
17 Cover on spring holder.
18 Spring holder
19 Spring for tape.
20 Stud for adjusting spring.
21 Headless set screw on stud for adjusting spring.
22 Wood handle for tape holder.
23 Round-head wood screw in tape holder.
24 Millivoltmeter.
25 Leads for connecting millivoltmeter with contact bars
26 Round-head screws for cover on tape holder.
27 Tape.
28 Contact screw on tape holder.
29 Leather strap.
30 Leather strap.

Rail Bond Testers



A. S. & W. Rail Bond Tester

Rail Bond Testers

(See pages 41 and 42)

Directions for Setting Up and Using Crown Rail Bond Tester

This testing apparatus has recently been simplified and greatly improved. To set up this apparatus, turn the short horizontal contact bar 27 at right angles to the handle and fasten in this position with the thumb nut 6. Close the small battery switch on the side of the testing box. This switch should be kept open at all times, except when the instrument is not in use, otherwise when the contact points 23 rest on any conducting substance, the battery in the testing box will run down. Adjust the telephone receiver 16 to the ear by means of the head piece and connect the receiver to the two binding posts 15 on the testing box. The apparatus is now ready for testing.

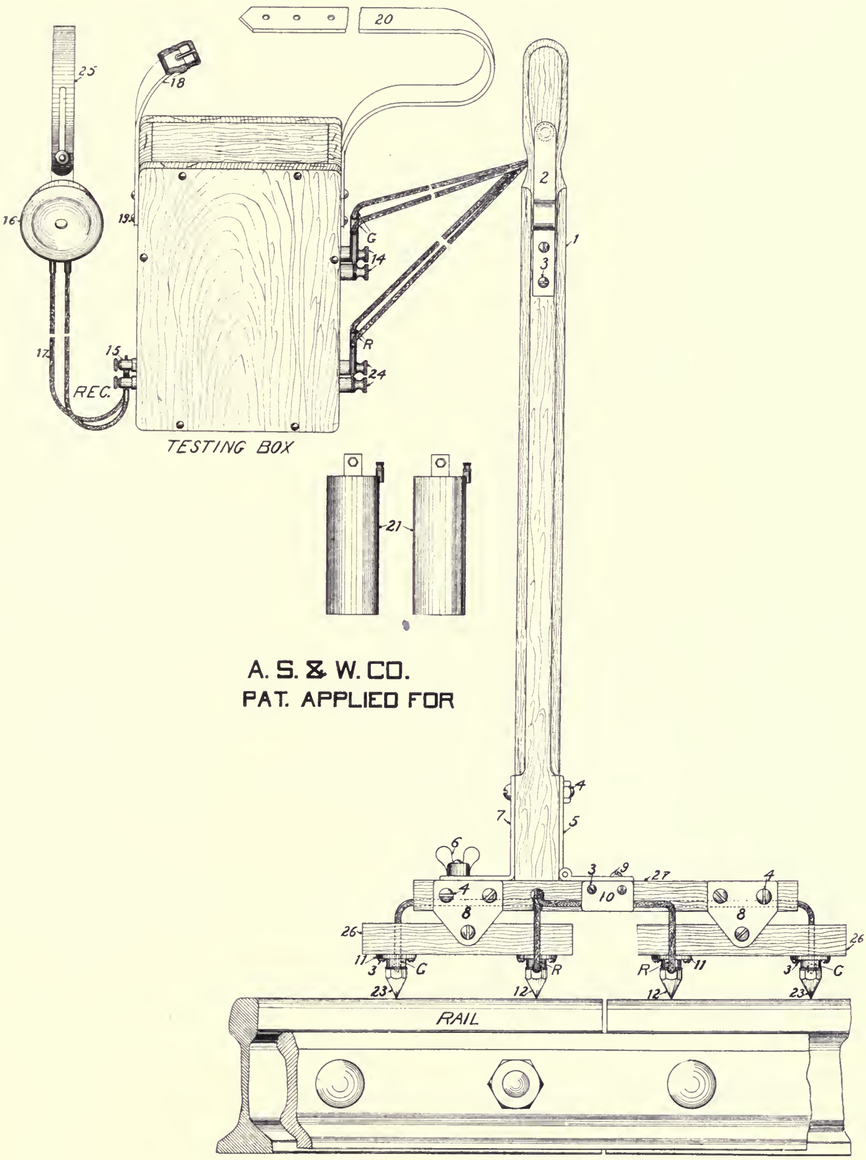
Place the contact bar carrying the four contact points across the rail joint to be tested so as to bring the joint midway between the two central contact points. If the two outer points make good contact with the rail a certain definite tone will be produced in the receiver. This tone, called the first tone, will be nearly constant in intensity for all conditions of rail joints except those which are entirely open. By pressing the spring contact point down on the rail with the foot, a second tone, usually differing from the first, will be produced. *When this second tone is equal to the first in intensity, the resistance of the joint will be equal to that of approximately* 6 *feet of* 70*-pound rail, or* 0.00009 *ohm.* When the second tone is *less* intense than the first tone the resistance of the joint will be *less* than 6 feet of 70-pound rail and the softer the switch tone the better the condition of the joint. If, however, the second tone is *more intense* than the first tone the resistance of the joint is *greater* than that of 6 feet of 70-pound rail, and the louder the second tone with respect to the first, the greater the resistance of the joint. Joints which give no first tone at all but an extremely loud second tone, may be considered as open circuited. If no second tone can be obtained differing from the first tone, then one of the two inner contact points probably does not contact with the rail. If both first and second tones are extremely faint, or if they are intermittent, the battery is running very weak and it should be replaced by a new battery.

Keep the four contact points sharp and maintain a good, clean and tight electrical connection between the contact points and the wires. Do not burn out the instrument on an open and arcing rail joint. The longer the contact bar is allowed to remain on each joint the quicker the battery will run down, because they are short circuited through the rail joints. A little practice will soon enable one to determine the condition of a joint very quickly.

List of Parts for Crown Rail Bond Tester

1 Handle.
4 Bolts on handle and hinge joints.
5 Hinge on handle.
8 Plate for hinge joint.
10 Plate on connecting bar.
11 Contact screw holder.
12 Contact screw points.
15 Binding post for receiver cords.
16 Telephone receiver.
17 Telephone receiver cords.
21 Dry cells in testing box.
25 Head piece for receiver.
26 Short bar for contact points.
27 Connecting bar.

Rail Bond Testers

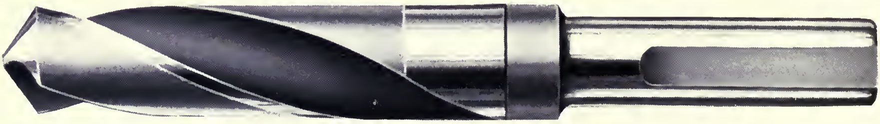


Crown Rail Bond Tester

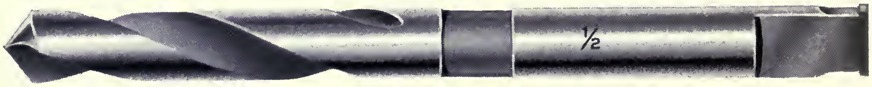
Hand Tools

Portable Drill Grinder No. 16 (Clark)

We again call attention to the importance of keeping drill points very sharp and properly shaped. This cannot be emphasized too strongly. A dull or poorly sharpened drill point greatly increases the amount of power required for operating the machine. It may, in fact, require enough to break the machine, and will always lead to enlarged or roughened holes. We show, on these two pages, a light portable hand drill grinder, which every railway company should possess, so that their men can sharpen the drills while they are working on the track. This machine can be readily attached to any support, and operated by hand. In sharpening points, give them exactly the same angles, and make them look exactly like *new* drill points, then they will cut smoothly and easily.



6-inch Blacksmith's Drill



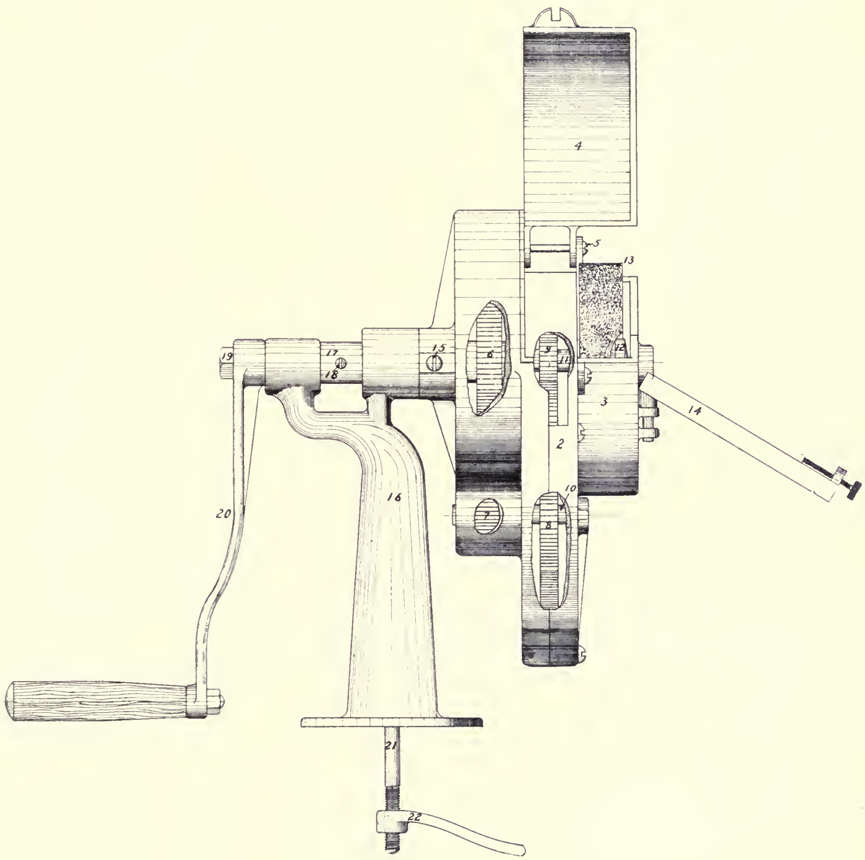
One-half Inch Twist Drill No. 12

The above ½-inch twist drill is used on all of our multiple spindle drilling machines for twin terminal and type B. S. B. rail bonds. It has a specially formed shank designed for the spindles of these machines.

The standard blacksmith's drill shown above is used in all of our single spindle machines. The drill is approximately 6 inches long over all, and can be used in varying diameters up to 1⅛ inches. Its shank is $\frac{21}{32}$-inch in diameter by 2 inches long. Made special for drill 21 M.

These drills are kept in stock for immediate shipment, at reasonable prices.

Hand Tools



List of Parts for Hand Drill Grinder No. 16

1 Back casting.
2 Front casting.
3 Front bearing casting.
4 Wheel cover.
5 Bolt for wheel cover.
6 Large drive gear.
7 Pinion on intermediate shaft.
8 Large gear on intermediate shaft.
9 Pinion on wheel shaft.
10 Intermediate shaft.
11 Wheel shaft.
12 Collar on wheel shaft.
13 Emery wheel.
14 Drill holder.
15 Set screw on back casting.
16 Stand.
17 Collar on driving stud.
18 Set screw for collar on driving stud.
19 Driving stud.
20 Crank handle.
21 T-bolt on stand.
22 Clamping nut on T-bolt.

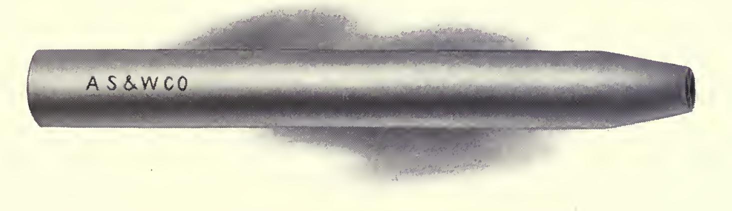
Hand Tools

Tap Style of Groove Cutter No. 16, for Form C Twin Terminal Bond

Hand Groove Cutter No. 14

The two styles of groove cutters shown above are used in cutting threads or a groove in the wall of the hole drilled in steel for twin terminal bonds, as described on page 53. No. 16 cutter should always be used in connection with form C twin terminal bonds, while No. 14 gives best results with forms A and B bonds.

Hand Tools



Blunting Punch No. 11

The punch No. 11 is used to dull the outer edge of the holes to prevent scarfing the copper terminal studs as they are inserted in the holes.

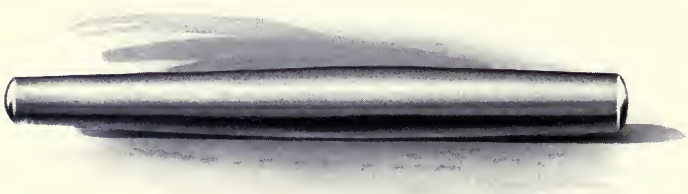
Expanding Hammer No. 10

The three-pound hammer No. 10 has a long flexible handle and is especially suited for installing twin terminal bonds.

Hand Tools

Driver for Form C Twin Terminal Bond No. 17

The special punch or set No. 17 is used when installing form C twin terminal bonds, which are placed on Weber joints. The horizontal angle of this style of joint prevents the direct driving of the terminal studs.



Steel Taper Punch No. 12
(See table I, page 17)

This No. 12 punch should always be used in the installation of tubular terminal bonds, as explained on page 15. It is made of a high grade steel, and given a special temper. Made in different sizes for different sized terminals.

Part IV

We are extensive manufacturers of iron, steel and copper wire of every description—round, flat, square, triangular and odd shape—for mechanical and electrical purposes. A few of these products will be briefly catalogued in this section.

We make electrical wires and cables, both solid and stranded, of any capacity, for all purposes. Insulated with paper, varnished cambric or with our special Crown or Globe, or 30 per cent rubber. These are lead encased, steel armored or protected in any other way required for aerial, underground or submarine service, as used in connection with incandescent lighting or distribution of power.

American wire rope, heavy cables and hawsers; elevator, tramway, derrick ropes and extra flexible rope.

American Railway Fences, for right of way and all other service. Also fence gates and steel fence posts.

Inquiries accompanied by specifications respectfully solicited. Write for catalogues. Prices quoted on application.

Notes on Electricity

SO far as the practical electrical worker or engineer is concerned, electricity may be considered as one of the various forms of energy. Being such, it is never created, but is always produced at the expense of an equal or greater amount of energy in some other form. Energy in the form of electricity serves no useful purpose as such. It must be transformed back into some useful form of energy such as mechanical, chemical or thermal before it can be utilized. Electrical energy must always be used when it is produced, and produced when needed for it cannot be stored. Because of the ease of transforming it into other useful forms of energy, and of transferring it over great distances, electricity is being utilized more and more for commercial purposes. The ultimate nature of electricity is unknown, though recent discoveries would indicate that matter itself is composed of ultimate particles or charges of electricity.

Electric Current This may be defined as the quantity of electricity per second which passes through any circuit or conductor when the flow is uniform. An electric current is thought to be transmitted through a conductor by being handed on from particle to particle. The electric current (transformed) is that which does work. It heats the conductor, furnishing heat and light; it turns the motor armature, furnishing mechanical power. It deposits the metal in the electrolytic cell, and it is the source of the lifting power of the electro magnet. Current is measured by ammeters, instruments through which all of the current passes.

A current which continues flowing in the same direction no matter how its strength may vary, is called a continuous current, or sometimes a direct current (D. C.). If the strength of such a current is constant, it is called an unvarying current; if its strength is not constant, it is a varying continuous current. A regular varying continuous current is called a pulsatory current. A current which alternately flows in opposite directions, no matter how its strength may vary, is called an alternating current (A. C.). This may be periodic or non-periodic. The continuous or direct current is generally used where small amounts of power are involved, as in telephone and telegraph and bell circuits, also in cases where large amounts of power are to be transmitted through comparatively short distances, as in the lighting of a large building or operation of a small railway system. When electric energy in quantity is to be transferred over long distances or distributed over wide areas, alternating currents are used to reduce the cost of the necessary copper.

The practical unit of current is the *ampere*. The value of an ampere is equal to one-tenth of unit current in the C. G. S. system of electro-magnetic units, and is represented with sufficient accuracy for practical purposes by the unvarying current, which, when passed through a solution of nitrate of silver

Notes on Electricity

in water, in accordance with certain specifications, deposits silver at the rate of 0.001118 of a gramme per second. It is that current which will flow in a circuit having a resistance of one ohm and a voltage pressure of one volt.

Voltage The direct cause of a flow of current is a propelling or driving force in the circuit called an *electromotive force* (e. m. f.) or a *difference of potential* or *voltage difference.* This may be compared to a flow of water through a pipe line connecting two reservoirs. As long as both reservoirs remain at the same level (or potential) there will be no flow; when one is raised above the other a pressure or head will be established (similar to a difference of potential, or e. m. f. in a circuit) which will cause a flow. It is the primary function of all electrical generators to produce this e. m. f. Thus the two unconnected poles of a battery or dynamo in operation, are at different potentials, they are charged with opposite kinds of electricity, positive and negative, and this e. m. f. will cause a current to flow when the poles are connected by a conductor. If this connecting conductor be opened at any point, the full voltage of the generator will be found at the separated points, the region between them will be under electric stress, and the electronic transfer will cease.

The practical unit of e. m. f. is called a *volt.* A volt is such electromotive force as would cause a current of one ampere to flow against a resistance of one ohm. Volts are measured by voltmeters, through which a very small portion of current, or none, passes.

Circuit The complete path through which a current flows is called a circuit. There must always be at least three parts to any circuit, an electric generator, a receiving device in which the electric energy is transferred into useful energy, such as a motor or electric lights, or both, and two conductors, the feeder and the return, which connect the generator with the receiver. Under certain unfavorable conditions the conductors may become the receiver, in which case all the electric energy will be dissipated as heat. In D. C. railway circuits the overhead feeder system is usually connected with the positive dynamo brush, and the grounded track return is connected with the negative brush. If the rails are poorly bonded or heavily loaded, the current will divide and some of it will return or be *shunted* through the earth or through parallel pipe lines and the earth to the generator.

In commercial work only three of the pure metals are used as conductors—copper, aluminum and iron. Of these the first is pre-eminently the best, while next in order come aluminum and iron. The last is used almost exclusively for telegraph work and for the return portion of railway circuits.

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A circuit is said to be *grounded* when any metallic portion is connected to ground. The grounded portion will be at zero potential, or at the potential of the earth. If but one point of a circuit is grounded, no current will flow into ground, but if two or more points are grounded, some current will escape into ground, for the ground between such points then becomes a "parallel" or shunt circuit, and the current will divide between the two paths. If no part of a circuit is grounded, it is said to be *insulated*. Conductors may be insulated (a) by supporting them on *insulators* or substances which conduct little or no electricity, or (b) by covering them throughout their length with some form of *insulation* or dielectric material which will not conduct electricity.

The conducting power of any substance of unit dimensions is called its *conductivity*. The commercial standard of conductivity in this country is the one established by Dr. Matthiesen in 1861. It is that of a piece of supposedly pure copper wire of constant cross-section meeting the following specifications: *

Specific gravity, 8.89.
Length, 1 meter, or 39.3704 inches.
Weight, 1 gram, or 15.432 grains.
Resistance, 0.141729 ohm at 0° C.
Specific resistance, 1.594 microhms per cubic centimeter, or 0.6276 microhm per cubic inch at 0° C.

Much of the copper now produced is higher in conductivity than Dr. Matthiesen's standard by one or two per cent, owing to improved methods of refining copper. It is usual, however, to specify that soft drawn copper shall have 98 per cent conductivity, and hard drawn copper 97 per cent of Matthiesen's standard.

The diameter of a conductor is usually expressed in *mils*. A *circular mil*, is very generally taken as the unit of area in considering the cross-section or carrying capacity of electrical conductors. This is the area of a circle whose diameter is one mil, or one-thousandth of an inch. It equals .7854 of a square mil. This unit area possesses several advantages in making wiring calculations and in determining the relations between different wires having known diameters. The cross-section of any solid round wire in circular mils is found by squaring the diameter of the wire in mils, and conversely, the diameter of a wire in mils is obtained by extracting the square root of the section expressed in circular mils. The constant π, which expresses the ratio between the circumference and diameter of any circle, does not enter into these calculations, thus greatly simplifying them.

Circular mils = square inches $\div$ .0000007854 = (diameter in mils)^2
Square inches = circular mils $\times$ .0000007854
One circular mil = .0005067087 square millimeter
One square millimeter = 1,973 circular mils
There are 1,273,236 circular mils in one square inch

* This and much of the following is taken from our "Electrical Wires and Cables" Catalogue and Handbook.

Notes on Electricity

Wire Gauges

The sizes of wires are ordinarily expressed in certain gauge numbers arbitrarily chosen. There are several independent gauge systems, and it is necessary in each case to specify the particular wire gauge used. Though the gauge numbers have the advantage of enabling manufacturers to carry wires in stock from which purchasers may choose with a reasonable assurance of quick delivery, there is nevertheless a tendency to do away with all gauge numbering methods and to distinguish different electrical wires by their diameters expressed in mils.

The American Standard or Brown & Sharpe gauge is used in America as the standard for copper wire used for electrical purposes. In this gauge both the sizes and the areas vary in geometrical progression. The diameters of wires are obtained from the geometric series, in which the first number, No. 4/0 = 0.46 inch in diameter, and No. 36 = .005 inch, the nearest fourth significant figure being retained in the areas and diameters so obtained.

The American Steel and Wire Co.'s gauge is used almost universally in this country for steel and iron wires, except galvanized telegraph and telephone wire which is always made to the Birmingham wire gauge.

The Birmingham wire gauge is used largely in England as their standard, and in this country for galvanized telegraph and telephone wires.

The following table gives the numbers and diameters in decimal parts of an inch for the various wire gauges used in this country and England.

Comparative Sizes Wire Gauges in Decimals of an Inch

No. of Wire Gauge	American Steel and Wire Co.'s Gauge	American Standard (B.&.S)Gauge	Birmingham or Stubs'	British Imperial Standard	Old English or London	French	No. of Wire Gauge	American Steel and Wire Co.'s Gauge	American Standard (B.&S.)Gauge	Birmingham or Stubs'	British Imperial Standard	Old English or London	French
0000000	.4900	. . .	. .	.500	. . .	. .	18	.0475	.04030	.049	.048	.0490	.238
000000	.4615	.58000	. .	.464	. . .	. .	19	.0410	.03589	.042	.040	.0400	.250
00000	.4305	.51650	.500	.432	. . .	. .	20	.0348	.03196	.035	.036	.0350	.263
0000	.3938	.46000	.454	.400	.4540	. .	21	.0317	.02846	.032	.032	.0315	.279
000	.3625	.40964	.425	.372	.4250	. .	22	.0286	.02535	.028	.028	.0295	.290
00	.3310	.36480	.380	.348	.3800	. .	23	.0258	.02257	.025	.024	.0270	.303
0	.3065	.32486	.340	.324	.3400	. .	24	.0230	.02010	.022	.022	.0250	316
1	.2830	.28930	.300	.300	.3000	.033	25	.0204	.01790	.020	.020	.0230	.331
2	.2625	.25763	.284	.276	.2840	.040	26	.0181	.01594	.018	.018	.0205	.342
3	.2437	.22942	.259	.252	.2590	.050	27	.0173	.01420	.016	.0164	.01875	.356
4	.2253	.20431	.238	.232	.2380	.063	28	.0162	.01264	.014	.0148	.01650	.371
5	.2070	.18194	.220	.212	.2200	.068	29	.0150	.01126	.013	.0136	.01550	.383
6	.1920	.16202	.203	.192	.2030	.083	30	.0140	.01003	.012	.0124	.01375	.394
7	.1770	.14428	.180	.176	.1800	.097	31	.0132	.00893	.010	.0116	.01225	.408
8	.1620	.12849	.165	.160	.1650	.110	32	.0128	.00795	.009	.0108	.01125	.419
9	.1483	.11443	.148	.144	.1480	.120	33	.0118	.00708	.008	.0100	.01025	.431
10	.1350	.10189	.134	.128	.1340	.135	34	.0104	.00630	.007	.0092	.00950	.448
11	.1205	.09074	.120	.116	.1200	.149	35	.0095	.00561	.005	.0084	.00900	.458
12	.1055	.08081	.109	.104	.1090	.162	36	.0090	.00500	.004	.0076	.00750	.472
13	.0915	.07196	.095	.092	.0950	.172	37	.0085	.00445	....	.0068	.00650	.485
14	.0800	.06408	.083	.080	.0830	.185	38	.0080	.00396	....	.0060	.00575	.499
15	.0720	.05706	.072	.072	.0720	.197	39	.0075	.00353	....	.0052	.00500	.509
16	.0625	.05082	.065	.064	.0650	.212	40	.0070	.00314	....	.0048	.00450	.524
17	.0540	.04525	.058	.056	.0580	.225							

Notes on Electricity

Resistance All substances offer a resistance to the passage of an electric current through them. The resistance of a substance may be defined as that inherent physical property, depending on temperature, molecular construction, and dimensions, which modifies the strength of current flowing through it. Resistance bears a reciprocal relation to conductivity, the greater the one the less the other.

The practical unit of resistance is the *international ohm*, which is the resistance offered to an unvarying electric current by a column of pure mercury at a temperature of melting ice, 14.4521 grams (0.51 ounce) in mass, of a constant cross-sectional area, and 106.3 centimeters (41.85 inches) in length. To obtain a concrete idea of this unit it may be remembered that a copper wire having a diameter of one-tenth of an inch (No. 10 B. and S. gauge) has at 68 degrees F. a resistance of approximately one ohm per thousand feet, or 5.28 ohms per mile.

Resistance varies greatly with different metals and is in general less for a pure metal than for any of its alloys. Its value will in every case depend upon the relation of three factors, the length of the wire, its cross-sectional area, and the nature or chemical composition of the metal, all of which vary with temperature. Increasing or decreasing the length (L) of any conductor will increase or decrease the resistance (R) of the conductor in direct proportion. Increasing or decreasing its sectional area (A) will inversely affect its resistance, that is, as the section of the conductor increases the resistance becomes proportionately less, and conversely. The term conductor as used in this connection should be taken in its broadest sense, meaning the whole length of any circuit or any portion of a circuit under consideration, whether it be in a straight or curved line or wound in a coil.

For example: One mile of any given wire will have twice the resistance of one-half mile of the same wire, or 5.28 times the resistance of 1000 feet. Again, if we have two wires of equal length, one of which has a sectional area five times as great as that of the other, then, assuming uniform quality and treatment, the electrical resistance of the larger wire will be one-fifth that of the smaller, and as the weight per unit length varies directly as the sectional area, it follows that the resistance of a wire weighing, for example, 500 pounds per mile, will equal one-fifth the resistance of a wire weighing 100 pounds per mile, assuming uniform quality and treatment as before.

Algebraically, these relations may be expressed thus:

$$R = K \times (L \div)$$

Where (K) is a constant for any metal and represents its *resistivity* or *specific resistance.*

Resistivity, a factor depending only on the material or structure of the metal, as compared with pure copper as unity, may be expressed in a number

Notes on Electricity

of different ways, all being equivalent to the resistance of some unit of cross-section. This unit may be expressed either in linear dimensions or as a combination of weight and dimensions. It may represent the resistance measured between opposite faces of a unit cube of the metal. Or, another and more common way of expressing resistivity is in terms of *ohms per mil-foot*, meaning the resistance of a round wire one foot long, having a diameter of one mil or .001 inch and an area of one circular mil. With this unit, the resistance of any wire is found by multiplying its length (L) by its resistivity (K, below) in ohms per mil-foot and dividing this product by the section area expressed in circular mils.

Physical Properties of Copper, Aluminum, Iron and Steel Wire

Physical Properties		Copper		Aluminum 99 Per Cent Pure	Iron (Ex. B. B.)	Steel (Siemens Martin)
		Annealed	Hard Drawn			
Conductivity, Matthiesen's standard		99 to 102	96 to 99	61 to 63	16.8	8.7
Ohms per mil-foot at 68° F. = 20° C. (K.)		10.36	10.57	16.7	62.9	119.7
Ohms per mile at 68° F. = 20° C.		$\frac{54,600}{\text{cir. mils}}$	$\frac{55,700}{\text{cir. mils}}$	$\frac{88,200}{\text{cir. mils}}$	$\frac{332,000}{\text{cir. mils}}$	$\frac{632,000}{\text{cir. mils}}$
Pounds per mile-ohm at 68° F. = 20° C.		875	896	424.0	4700	8900
Temperature coefficient of resistivity per degrees F. at 32° F.		.00238	.00238	.0022	.0028	
Temperature coefficient of resistivity per degrees C. at 0° C.		.00428	.00428	.0040	.0050	
Specific gravity. Mean values		8.89	8.94	2.68	7.77	7.85
Pounds per 1000 feet per circular mil		.003027	.003049	.000909	.002652	.002671
Weight in pounds per cubic inch		.320	.322	.0967	.282	.283
Specific heat. Mean values		.093	.093	.214	.113	.117
Melting point in degrees F. Mean values		2012	2012	1157	2975	2480
Melting point in degrees C. Mean values		1100	1100	625	1635	1360
Mean coefficient of linear expansion. Degrees F.		.00000950	.00000950	.00001285	.00000673	.00000662
Mean coefficient of linear expansion. Degrees C.		.0000171	.0000171	.0000231	.000120	.000118
Solid Wire Pounds per square inch	Tensile strength	30,000 to 42,000	45,000 to 68,000	20,000 to 35,000	50,000 to 55,000	100,000 to 120,000
	Elastic limit	6,000 to 16,000	25,000 to 45,000	14,000	25,000 to 30,000	50,000 to 72,000
	Modulus of elasticity	7,000,000 to 17,000,000	13,000,000 to 18,000,000	10,500,000 to 11,500,000	22,000,000 to 27,000,000	22,000,000 to 27,000,000
Concentric Strand Pounds per square inch	Tensile strength	29,000 to 37,000	43,000 to 65,000	25,800	. . .	98,000 to 118,000
	Elastic limit	5,800 to 14,800	23,000 to 42,000	13,800	. . .	45,000 to 55,000
	Modulus of elasticity	5,000,000 to 12,000,000	12,000,000 to 14,000,000	Approx. 10,000,000	. . .	16,000,000 to 22,000,000

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Bare Copper Wire Table

The data from which these tables have been computed are as follows: Matthiesen's standard resistivity, Matthiesen's temperature coefficients, special gravity of copper=8.89. Resistance in terms of the international ohm.

American Standard (B. & S.) Gauge	Diameter of Wire			Cross-sectional Area		
	In Inches	Allowable Variation in Per Cent Either Way	In Millimeters	Circular Mils (d^2) d = .001 Inch	Square Inch (d^2 x .7854)	Square Millimeter
0000	.4600	.45	11.68	211600.	.166190	107.219
000	.4096	.50	10.40	167772.	.131770	85.011
00	.3648	.50	9.266	133079.	.104520	67.432
0	.3250	.50	8.255	105625.	.082958	53.521
1	.2893	.50	7.348	83694.	.065733	42.408
2	.2576	.50	6.543	66358.	.052117	33.624
3	.2294	.75	5.827	52624.	.041331	26.665
4	.2043	.75	5.189	41738.	.032781	21.149
5	.1819	.75	4.620	33088.	.025987	16.766
6	.1620	.75	4.115	26244.	.020612	13.298
7	.1443	.75	3.665	20822.	.016354	10.550
8	.1285	1.00	3.264	16512.	.012969	8.3666
9	.1144	1.00	2.906	13087.	.010279	6.6313
10	.1019	1.00	2.588	10384.	.0081553	5.2614
11	.0907	1.00	2.304	8226.5	.0064611	4.1684
12	.0808	1.25	2.052	6528.6	.0051276	3.3081
13	.0720	1.25	1.829	5184.0	.0040715	2.6267
14	.0641	1.25	1.628	4108.8	.0032271	2.0819
15	.0571	1.25	1.450	3260.4	.0025607	1.6520
16	.0508	1.50	1.290	2580.6	.0020268	1.3076
17	.0453	1.50	1.151	2052.1	.0016117	1.0398
18	.0403	1.50	1.024	1624.1	.0012756	.82294
19	.0359	1.75	.9119	1288.8	.0010122	.65304
20	.0320	1.75	.8128	1024.0	.00080425	.51887
21	.0285	1.75	.7239	812.25	.00063794	.41157
22	.0253	1.75	.6426	640.09	.00050273	.32434
23	.0226	2.00	.5740	510.76	.00040115	.25880
24	.0201	2.00	.5105	404.01	.00031731	.20471
25	.0179	2.00	.4547	320.41	.00025165	.16235
26	.0159	2.00	.4039	252.81	.00019856	.12810
27	.0142	2.00	.3607	201.64	.00015837	.10217
28	.0126	2.00	.3200	158.76	.00012469	.08044
29	.0113	2.00	.2870	127.69	.00010029	.06470
30	.0100	2.50	.2540	100.00	.000078540	.05067
31	.00893	3.00	.2268	79.74	.000062631	.04040
32	.00795	3.00	.2019	63.20	.000049639	.03202
33	.00708	3.00	.1798	50.13	.000039369	.02540
34	.00630	3.50	.1600	39.69	.000031173	.02011
35	.00561	4.00	.1425	31.47	.000024718	.01594
36	.00500	4.50	.1270	25.00	.000019635	.01266
37	.00445	5.00	.1130	19.80	.000015553	.01003
38	.00396	6.00	.1006	15.68	.000012316	.00794
39	.00353	7.00	.08966	12.46	.0000097868	.00631
40	.00314	8.00	.07976	9.86	.0000077437	.00499

Notes on Electricity

Bare Copper Wire Table—Continued

Giving dimensions, weights, lengths and resistances of bare round solid wires, Matthiesen's Standard of Conductivity. While these values are theoretically correct, slight variation should be expected in practice.

Pounds per		Ohms per			Feet per		American Standard (B. & S.) Gauge
1000 Feet	Ohm at 20 C. 68 F.	Pound at 20 C. 68 F.	1000 Feet at 20 C. 68 F.	1000 Feet at 50 C. 122 F.	Pound	Ohm at 20 C. 68 F.	
640.5	13,090	.0000764	.04893	.05467	1.561	20,440	0000
508.0	8,232	.0001215	.06170	.06893	1.969	16,210	000
402.8	5,177	.0001931	.07780	.08692	2.482	12,850	00
319.5	3,256	.0003071	.09811	.1096	3.130	10,190	0
253.3	2,048	.0004883	.1237	.1382	3.947	8,083	1
200.9	1,288	.0007765	.1560	.1743	4.977	6,410	2
159.3	810.0	.001235	.1967	.2198	6.276	5,084	3
126.4	509.4	.001963	.2480	.2771	7.914	4,031	4
100.2	320.4	.003122	.3128	.3495	9.980	3,197	5
79.46	201.5	.004963	.3944	.4406	12.58	2,535	6
63.02	126.7	.007892	.4973	.5556	15.87	2,011	7
49.98	79.69	.01255	.6271	.7007	20.01	1,595	8
39.63	50.12	.01995	.7908	.8835	25.23	1,265	9
31.43	31.52	.03173	.9972	1.114	31.82	1,003	10
24.93	19.82	.05045	1.257	1.405	40.12	795.3	11
19.77	12.47	.08022	1.586	1.771	50.59	630.7	12
15.68	7.840	.1276	1.999	2.234	63.79	500.1	13
12.43	4.931	.2028	2.521	2.817	80.44	396.6	14
9.858	3.101	.3225	3.179	3.552	101.4	314.5	15
7.818	1.950	.5128	4.009	4.479	127.9	249.4	16
6.200	1.226	.8153	5.055	5.648	161.3	197.8	17
4.917	.7713	1.296	6.374	7.122	203.4	156.9	18
3.899	.4851	2.061	8.038	8.980	256.5	124.4	19
3.092	.3051	3.278	10.14	11.32	323.4	98.66	20
2.452	.1919	5.212	12.78	14.28	407.8	78.24	21
1.945	.1207	8.287	16.12	18.01	514.2	62 05	22
1.542	.07589	13.18	20.32	22.71	648.4	49.21	23
1.223	.04773	20.95	25.63	28.63	817.6	39.02	24
.9699	.03002	33.32	32.31	36.10	1,031	30.95	25
.7692	.01888	52.97	40.75	45.52	1,300	24.54	26
.6100	.01187	84.23	51.38	57.40	1,639	19.46	27
.4837	.007466	133.9	64.79	72.39	2,067	15.43	28
.3836	.004696	213.0	81.70	91.28	2,607	12.24	29
.3042	.002953	338.6	103.0	115.1	3,287	9.707	30
.2413	.001857	538.4	129.9	145.1	4,145	7.698	31
.1913	.001168	856.2	161.8	183.0	5,227	6.105	32
.1517	.0007346	1,361	206.6	230.8	6,591	4.841	33
.1203	.0004620	2.165	260.5	291.0	8,311	3.839	34
.09543	.0002905	3,441	328.4	366.9	10,480	3 045	35
.07568	.0001827	5,473	414.2	462.7	13,210	2.414	36
.06001	.0001149	8,702	522.2	583.5	16,660	1.915	37
.04759	.00007210	13,870	658.5	735.7	21.010	1.519	38
.03774	.00004545	22,000	830.4	927.7	26,500	1.204	39
.02993	.00002858	34,980	1047.0	1170.0	33,410	0.955	40

Notes on Electricity

For telephone and telegraph conductors it is customary to use still another unit of resistivity—*weight per mile-ohm*. This is the weight of a conductor one mile in length, which has a resistance of one ohm. It equals the product of the resistance per mile and the weight per mile. However great may be the variation in weight of wires of different sizes, the variation in resistance is equally great inversely, and so the balance is preserved.

To illustrate: If the mile-ohm be 5,000, the resistance of a wire weighing 1,000 pounds per mile will be 5 ohms, while a similar wire weighing 5 pounds per mile will have a resistance of 1,000 ohms. This method of expressing resistance is more direct than the others, which require interpretation before the results may be used in any calculation. Values for these various units will be found tabulated on page 151.

Temperature Effects on Resistance

Temperature bears an important part in all tests and calculations of electrical conductors, for their resistances vary directly with temperature. The resistance of copper wire increases about twenty-three one-hundredths and that of iron wire about twenty-eight one-hundredths per cent for each additional degree F.

Dr. Matthiesen, while experimenting with copper conductors, derived the following formula for the change of resistance with temperature in copper wire:

$$R = R_0 \ (1 + .00387t + .00000591t^2)$$

Later experiments have shown that for practical engineering purposes all terms below the second may be dropped, and that the above equation for temperature changes in copper wire may now be written:

$$R_t = R_0(1 + .0042t) \text{ for t in degrees C. or}$$

$$R_t = R_0(1 + .0023t) \text{ for t in degrees F.}$$

Where R_0 = Resistance at 0° C.

R_t = Resistance at any temperature t°.

The general equation for any conductor is usually written:

$$R_t = R_0(1 + a t), \text{ where}$$

a is called the *temperature coefficient* of the conductor. These coefficients vary considerably with the purity of metals, and they change slightly even in the purest metals. The following average values of the temperature coefficient have been found, experimentally, at 0° C.

Metals	Centigrade	Fahrenheit
Aluminum	.0040	.0022
Copper	.00428	.00238
Gold	.0038	.0021
Mercury	.0007	.0004
Platinum	.0025	.0014
Silver, annealed	.0040	.0022
Soft iron	.0050	.0028
Tin	.0044	.0025
Zinc	.0041	.0023

Notes on Electricity

Pounds per Mile-ohm of Copper Wire at Various Temperatures and Conductivities

Per Cent Conductivity Matthiesen's Standard	Pounds per Mile-ohm				Per Cent Conductivity Matthiesen's Standard	Pounds per Mile-ohm			
	At 32° F. 0° C.	At 60° F. 15.6° C.	At 68° F 20° C.	At 104° F. 40° C.		At 32° F. 0° C.	At 60° F. 15.6° C.	At 68° F. 20° C.	At 104° F. 40° C.
96.0	841.9	893.4	908.7	980.8	99.0	816.4	866.3	881.1	951.0
.2	840.2	891.5	906.8	978.7	.2	814.8	864.6	879.4	949.1
.4	838.4	889.7	904.9	976.7	.4	813.1	862.8	877.6	947.2
.6	836.7	887.8	903.0	974.7	.6	811.5	861.1	875.8	945.3
.8	835.0	886.0	901.2	972.7	.8	809.9	859.4	874.1	943.4
97.0	833.2	884.2	899.3	970.6	100.0	808.2	857.6	872.3	941.5
.2	831.5	882.4	897.4	968.7	.2	806.6	855.9	870.6	939.6
.4	829.8	880.5	895.6	966.7	.4	805.0	854.2	868.8	937.8
.6	828.1	878.7	893.8	964.7	.6	803.4	852.5	867.1	935.9
.8	826.4	876.9	891.9	962.7	.8	801.8	850.8	865.4	934.1
98.0	824.7	875.1	890.1	960.7	101.0	800.2	849.2	863.7	932.2
.2	823.1	873.4	888.3	958.8	.2	798.7	847.5	862.0	930.4
.4	821.4	871.6	886.5	956.8	.4	797.1	845.8	860.3	928.5
.6	819.7	869.8	884.7	954.9	.6	795.5	844.1	858.6	926.7
.8	818.1	868.1	882.9	953.0	.8	794.0	842.5	856.9	924.9
					102.0	792.4	840.8	855.2	923.1

Data Relating to Bare Copper Strand

Approximate Values

Size B. & S.	Circular Mils	Area Strand Square Inches	Number Wires in Strand	Diameter Each Wire Inches	Diameter of Strand Inches	Weight per 1000-Foot Strand Pounds	Weight per Mile Pounds	Resistance per 1000 Feet at 68° F. or 20° C.
	2,000,000	1.56874	91	.1482	1.6302	6204.8	32761.	.00530
	1,750,000	1.36494	91	.1387	1.5257	5429.3	28667.	.00607
	1,500,000	1.17831	91	.1284	1.4124	4653.6	24571.	.00707
	1,250,000	.98170	91	.1172	1.2892	3878.0	20475.	·00852
	1,000,000	.78494	61	.1280	1.1520	3100.3	16370.	.01060
	950,000	.74618	61	.1248	1.1232	2945.3	15551.	.01115
	900,000	.70724	61	.1215	1.0935	2790.3	14733.	.01179
	850,000	.66852	61	.1181	1.0629	2635.3	13914.	.01247
	800,000	.62810	61	.1145	1.0305	2480.2	13096.	.01325
	750,000	.58922	61	.1109	.9981	2325.2	12277.	.01413
	700,000	.54954	61	.1071	.9639	2170.2	11459.	.01514
	650,000	.51020	61	.1032	.9288	2015.2	10640.	.01630
	600,000	.47146	61	.0992	.8928	1860.2	9822.	.01767
	550,000	.43181	37	.1219	.8533	1703.0	8992.	.01925
	500,000	.39237	37	.1162	.8134	1548.2	8175.	.02116
	450,000	.35234	37	.1103	.7721	1393.4	7357.	.02349
	400,000	.31431	37	.1040	.7280	1238.5	6539.	.02648
	350,000	.27512	37	.0973	.6811	1083.34	5720.	.03026
	300,000	.23591	19	.1256	.6285	926.01	4889.	.03531
	250,000	.19635	19	.1147	.5738	771.67	4074.	.04233
0000	211,600	.16609	19	.1055	.5275	653.14	3448.5	.04997
000	167,772	.13187	19	.0940	.4700	512.07	2703.7	.06293
00	133,079	.10429	7	.1380	.4134	406.98	2148.9	.07935
0	105,625	.08303	7	.1228	.3684	322.39	1702.2	.10007
1	83,694	.06559	7	.1093	.3279	255.45	1348.8	.12617
2	66,358	.05205	7	.0973	.2919	202.5	1069.2	.15725
3	52,624	.04132	7	.0867	.2601	160.6	848.0	.19827
4	41,738	.03276	7	.0772	.2316	127.4	672.7	.25000
6	26,244	.02059	7	.0612	.1836	80.1	422.9	.39767
8	16,512	.01298	7	.0486	.1458	50.4	266.1	.62686
10	10,384	.00815	7	.0385	.1155	31.7	167.4	1.00848
12	6,528	.00511	7	.0305	.0915	19.9	105.0	1.59716
14	4,108	.00322	7	.0242	.0726	12.5	66.0	2.54192

Notes on Electricity

Ohm's Law In any circuit or portion of circuit through which a current flows there is always a fixed numerical relation between the current, the voltage and the resistance. This relation was first discovered and formulated into a law by Ohm, a noted German scientist. This law states that *the current which flows in the circuit equals the electric pressure divided by the resistance of the circuit.* ($I = E \div R$.) Under any given set of conditions the resistance of a circuit will remain nearly constant. The current flowing through this circuit will then vary directly as the voltage, and conversely the potential drop across the ends of a circuit or any portion of a circuit will vary with the current strength and will equal the product of the current flowing times the resistance of the circuit or portion of circuit under consideration ($E = I \times R$). Thus, for example, if 100 amperes flow through a single rail having a resistance of .00043 ohm, the voltage drop from end to end of the rail will be $100 \times .00043 = .043$ volt. And if the resistance of the bonded joint were say .05 ohm, the potential drop across the joint would be 5 volts, and this would be indicated by a voltmeter connected across the joint.

Conductors are in *series* when they are connected end to end and when the same current flows successively through each. The total resistance of several resistances in series will equal the sum of the separate resistances. Thus we place five 100-volt incandescent lamps in series between the trolley and ground, and the same current passes through all of the lamps. Conductors are in *parallel* or multiple when the current divides among them or when only a separate portion of the main line current passes through each branch. For example, all of the electric cars on a system would be in parallel between the trolley and ground, the current operating the motors of one car would not flow through the motors of another car. That portion of the total current flowing through each parallel branch will be inversely proportional to the resistance of each branch. The total or combined resistance of several circuits in parallel will equal *the reciprocal of the sum of the reciprocals of the separate resistances*, or it will equal the reciprocal of the sum of the *conductances.*

Alternating Currents

In a D. C. circuit the same current passes continuously in one direction through the circuit, and it has a uniform strength in all parts of a series circuit. Just as much current enters the negative brush of the generator as leaves at the positive brush. In an alternating current circuit the current alternates or reverses regularly in direction 25 or 60 times a second. The number of complete cycles or double alternations per second is called the *frequency.* The action of an alternating current may be compared to that of water in a closed tube which is caused to move back and forth in the tube by the regular reciprocating motion of a close fitting piston. The body of water once set

Notes on Electricity

in motion would tend to continue in motion owing to its momentum, and when at rest it would resist motion owing to its inertia. Alternating currents, unlike direct currents, have two properties somewhat similar to these mechanical properties.

Induction The region surrounding any conductor carrying a current is filled with *magnetic flux*. This flux is due to the current and varies in strength with it. Any conductor lying in this region of varying flux density will have generated in it an e. m. f. opposite in direction to the generator e. m. f. There will be a *counter* e. m. f. induced in the current-carrying wire itself which will at all times oppose the impressed e. m. f. This action which is called *self-induction* tends to retard the building up of the current, and to prolong the current when it approaches zero value.

Capacity When an e. m. f. is impressed on a conductor, a certain current called a *charging current* will be required to fill or *charge* the conductor. These, like condensers, will absorb and retain a certain amount of electricity until the impressed e. m. f. is removed or reversed, at which time they will discharge back through the generator. The strength of the charging current will depend upon the impressed voltage, the frequency and the *capacity* of the circuit. When capacity is in series with induction in any circuit they tend to annul each other's effects.

In any alternating circuit then there are four quantities which have to be considered in determining the current strength, voltage, resistance, inductance and capacity, though the last two may be very small in some circuits. There is but one voltage acting in any portion of the circuit, and this will always be the resultant of three active voltages, the impressed, the inductive, which opposes the impressed, and the capacity voltage, which is in advance of the impressed. This resultant voltage may equal, be smaller than or at times may be much larger than the generator voltage at certain points in the circuit. Ohm's law holds true when the e. m. f. (E) is the *resultant* e. m. f., or when the resistance of the D. C. circuit (R) is replaced by the *impedance* of the A. C. circuit, and when all operations are figured geometrically. The impedance is a complex quantity depending upon resistance, inductance, capacity and frequency.

Watts Power may be defined as the rate of doing work or of expending energy. The unit of electric power is the *watt*. It equals the product of three factors, amperes, volts and *power-factor*, the latter of which is unity in all D. C. circuits. In A. C. circuits the power factor is a fraction obtained by dividing the true watts delivered and measured by a wattmeter by the apparent or volt-ampere watts. Since electric energy depends upon a product, either

Notes on Electricity

factor may be small, and the other correspondingly large without affecting the product. Thus, 1000 watts will equal 100 amperes times 10 volts, or 10 amperes times 100 volts. While we are dealing with the same amount of energy in each case, the 100 amperes in the first case will require a conductor 10 times larger than the 10 amperes in the second case, to conduct the energy with the same given loss in the conductor. The size of the conductor is determined by the current, not the e. m. f. One thousand watts are called a *kilowatt* (K. W.), and 746 watts of electric energy are equivalent to one-horse power of mechanical energy. Joules (w)=work done=watts times seconds.

Transformers Owing to its property of induction, alternating currents are used almost exclusively for transmitting electric energy over long distances. In these circuits the current must be small, requiring a small conductor, but the voltage may be very high, as high as 110,000 has been used in a few instances. Suppose three separate and entirely independent coils of uniform size of insulated wire were wrapped closely about each other and about a piece of soft iron. Let coil A have 1 complete turn, B 10 turns and C 100 turns. If an alternating current be sent through coil B, the following results will be obtained, neglecting losses: In the single turn A (coil C open) there will be *induced* an e. m. f. equal to $\frac{1}{10}$ that at the terminals of coil B, and a current will be produced 10 times as large. In coil C (coil A open) an e. m. f. will be induced 10 times as great as in coil B and a current $\frac{1}{10}$ as great will result. The same amount of power in watts will be involved in each case, but the relative amounts of current and voltage will have been transformed or changed. In the one case (A) the voltage has been "stepped down," in the other case (C) it has been "stepped up." This is the underlying principle of the commercial stationary transformer; it enables the generator voltage to be increased at will, with a corresponding change of current and cost of transmission conductors. At the receiving end of the line the voltage is stepped down sufficiently to be used in motors or lamps and the current is increased in equal ratio. Alternating currents can be converted to direct currents commercially only by means of a *converter*, which is a dynamo-electric machine having one armature and one field for converting alternating currents to direct currents, or direct currents to alternating currents.

Alternating Current Heating Effects If an alternating current be transmitted through a conductor, portions of the electrical energy supplied may be transformed into heat in four different ways, each resulting in an energy loss and in a corresponding reduction of the current-carrying capacity of the conductor.

Notes on Electricity

1. A definite amount of electrical energy will be required to overcome the ohmic resistance of the conductor, just as in the case with continuous currents. This is commonly known as the I^2R loss, where I is the effective current. (An effective current is one which will produce the same thermal effect as an equivalent direct current.)

2. Under certain conditions there will be loss of energy due to the *skin effect* of alternating currents. A current induced in a conductor builds up from the surface, and an appreciable period of time is required for the current to penetrate to the interior portions of the conductor. If the frequency be high the central portion of large conductors or of iron conductors may contribute nothing to the conducting powers of the conductor. This is equivalent to increasing the resistance of the conductor, or in effect the conductor will have a spurious resistance which will be greater than its real resistance. On account of this action the resistance of track rails may be increased seven or eight times when alternating currents are used.

3. *Foucault* or eddy currents may be induced in the conductor itself, or in the lead sheathing or in the steel armor wires of a cable by the rapidly changing alternating magnetic flux. Foucault currents are produced at the expense of energy supplied the conductor, and they are dissipated in the form of heat. This loss would be much greater in single conductor cables carrying alternating current than in two-conductor or three-conductor cables in which the outer resultant magnetic field should be very small. Placing a single-conductor alternating current cable in an iron conduit would very greatly increase the energy loss, and for that reason it is seldon done. This loss will be greater in solid conductors than in stranded conductors of equal section, and it will increase with thickness of lead sheath and with the diameter of the armor wires.

4. *Dielectric* hysteresis losses in the insulating material. This loss is somewhat similar in kind to the magnetic hysteresis loss in iron. A dielectric is a poor conducting material used for insulating conductors through which an electromotive force establishes a molecular strain or an electro-static field of flux. The total dielectric loss is due to the sum of a direct I^2R leakage of current through the dielectric and to the dielectric hysteresis loss, which is thought to be a function of the insulation resistance, varying inversely. The hysteresis loss in the dielectric of a cable is constant and independent of load. It increases with voltage, with the length of cable and with frequency. It may be lessened by increasing the thickness of the dielectric, by using a dielectric of low specific inductive capacity and by working at low voltage and low frequency. The loss is thought to be negligible in direct current systems and in low voltage alternating current distribution systems.

Notes on Electricity

Horse-power and Current Required for Electric Traction

(See also page 184)

Per Cent Grade	Horse-power and Current Required to Propel One Ton at the following Speeds in Miles per Hour																					
	4		6		8		10		12		15		20		25		30		35		40	
	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.	H. P.	Amps.
0	.21	.35	.32	.53	.43	.71	.53	.89	.64	1.06	.80	1.33	1.07	1.78	1.33	2.22	1.60	2.66	1.87	3.11	2.13	3.55
1	.43	.71	.64	1.07	.85	1.42	1.07	1.78	1.28	2.13	1.60	2.67	2.13	3.56	2.67	4.44	3.20	5.33	3.74	6.22		
2	.64	1.07	.96	1.60	1.28	2.13	1.60	2.67	1.92	3.20	2.40	4.00	3.20	5.33	4.00	6.66	4.80	8.00				
3	.85	1.42	1.28	2.13	1.71	2.84	2.13	3.55	2.56	4.27	3.20	5.33	4.27	7.12	5.33	8.88						
4	1.07	1.78	1.60	2.66	2.13	3.55	2.67	4.45	3.20	5.33	4.00	6.66	5.33	8.90								
5	1.28	2.13	1.92	3.20	2.56	4.27	3.20	5.33	3.84	6.40	4.80	8.00										
6	1.49	2.49	2.24	3.73	2.99	4.98	3.74	6.22	4.48	7.48												
7	1.71	2.85	2.56	4.27	3.41	5.69	4.27	7.12														
8	1.92	3.20	2.88	4.80	3.84	6.40																
9	2.13	3.56	3.20	5.33	4.27	7.12																
10	2.35	3.91	3.52	5.87	4.70	7.82																
11	2.56	4.27	3.85	6.40																		
12	2.78	4.63	4.16	6.93																		

The above table is based on the two formulæ given below. The formula for horse-power per car is given by the Westinghouse Electric and Manufacturing Company, as follows:

$$\text{Horse-power} = \frac{\text{Miles per hour x tractive effort}}{375}.$$

The tractive effort is commonly taken at 20 pounds per ton on a level, and 20 pounds additional for each per cent grade. For trailers, add 12 pounds per ton.

A formula for the current per car deduced from the above, assuming 90 per cent efficiency of motors and 500 volt circuit, is as follows:

$$\text{Amperes} = \frac{\text{Miles per hour x 20 x (weight of car in tons plus weight car x 100 x per cent grade)}}{225}.$$

As an example of the above, suppose it is desired that a 25-ton car ascend a 3 per cent grade at 20 miles per hour.

From the table under the column headed 20 miles per hour opposite 3 per cent grade—horse-power per ton = 4.27 and amperes per ton = 7.12; therefore horse-power per car = 25 x 4.27 = 106.75 horse-power and current per car = 25 x 7.12 = 178 amperes.

Notes on Electricity

Wiring Formulæ and Tables The current carrying capacity of a conductor is not only limited by its allowable temperature rise, but also by the allowable drop of potential. The potential difference required to transmit a given electric current through a conductor will vary directly as the resistance of the conductor and inversely as its cross-sectional area. The diameter of conductors used for long distance transmission purposes is usually determined by the drop of potential allowable, rather than from other electrical considerations.

For most practical purposes the following formulæ can be used to determine the size of copper conductors, current per wire, and weight of copper per circuit for any system of electrical distribution.

$$\text{Area of conductor in circular mils} = \frac{D \times W}{P \times E^2} K = C.\ M.$$

$$\text{Current in main conductor} = \frac{W}{E} T. \quad \text{From which } P = \frac{D \times W}{C.\ M. \times E^2} K$$

$$\text{Weight of copper} = \frac{D^2 \times W \times K \times A}{P \times E^2 \times 1{,}000{,}000}, \text{ pounds.}$$

In these equations the symbols used denote the following quantities:

W = total watts delivered.

D = distance of transmission, one way in feet.

E = voltage between main conductors at the receiving or consumers' end of circuit.

P = loss in line in per cent of power delivered, i. e., of W, this being a whole number. K, T and A are constants given in the following table:

Wiring Formulæ Constants

System	Values of A	Values of K					Values of T				
		Per Cent Power Factor					Per Cent Power Factor				
		100	95	90	85	80	100	95	90	85	80
1-phase, and D. C.	6.04	2160	2400	2660	3000	3380	1.00	1.05	1.11	1.17	1.25
2-phase-4 wire	12.08	1080	1200	1330	1500	1690	.50	.53	.55	.59	.66
3-phase-3 wire	9.06	1080	1200	1330	1500	1690	.58	.61	.64	.68	.72

These constants depend upon the system of distribution as well as the conditions of the circuit.

For continuous current K = 2160, T = 1 and A = 6.04.

For any particular power factor the value of K is obtained by dividing 2160, the value for continuous current, by the square of the power factor for single phase, and by twice the square of the power factor for three-wire three-phase or four-wire two-phase. The three wires of a three-phase circuit and the four wires of a two-phase circuit should all be of the same size, and each conductor should be of the cross-section, as obtained by the proper application of the first formula.

The following assumed values of power factors for circuits may be used in any calculation when their exact values are not known.

Incandescent lighting and synchronous motors, 95 per cent.

Notes on Electricity

Lighting and induction motors, 85 per cent.

Induction motors alone, 80 per cent.

For *continuous currents* and for railway feeder circuits, for lamp and motor outlets, the following formula for determining area of conductor is found more convenient to use.

$$\text{Circular mils} = \frac{10.8 \times \text{amperes} \times \text{length of circuit in feet.}}{\text{Volts permissible drop in wire.}}$$

For example: What size of wire would be required for an 800-foot circuit carrying current to a 500-volt, 20-kilowatt, direct current motor, allowing 2 per cent drop in the circuit?

20 kilowatts = 20,000 watts.

$20,000 \div 500 = 40$ amperes in line.

1 per cent loss in each wire or branch of circuit $= 500 \times .01 = 5$ volts.

Length of each wire = 800 feet.

$$\text{Circular mils} = \frac{10.8 \times 40 \times 800}{5} = 69{,}120 \text{ or No. 2 B. \& S. wire say,}$$

for each branch of the circuit.

Power

Watts = unit of electric power = h. p. × 746.
Watts = current × volts × power factor.
Watts = foot-pounds per sec. ÷ 1.355.

1 kw. hour =
- 3412 B. t. u.
- 2,654,156 foot-pounds.
- 3.53 pounds water evaporated at 212° F.
- 22.8 pounds water raised from 62° to 212° F.
- 0.235 pound carbon oxidized at 100 per cent. eff.

Three-phase Formulæ—Unity Power Factor

POWER—If A = amperes per phase and V = delta voltage then $AV\sqrt{3}$ = total watts.

LINE DROP—If A = amperes per phase and R = resistance of one conductor then $AR\sqrt{3}$ = drop in delta voltage.

Arcing Distance of High Voltage Alternating Current Between Sharp Needle Points in Air

(Adopted by A. I. E. E.)

Effective Volts	Inches	Effective Volts	Inches	Effective Volts	Inches
5,000	.225	50,000	3.55	140,000	13.95
10,000	.47	60,000	4.65	150,000	15.00
15,000	.725	70,000	5.85	175,000	17.80
20,000	1.000	80,000	7.10	200,000	20.50
25,000	1.3	90,000	8.35	250,000	25.60
30,000	1.625	100,000	9.60	300,000	31.00
35,000	2.00	110,000	10.75	350,000	36.10
40,000	2.45	120,000	11.85	400,000	41.20
45,000	2.95	130,000	12.95		

Electric Railway Material

Trolley Wire

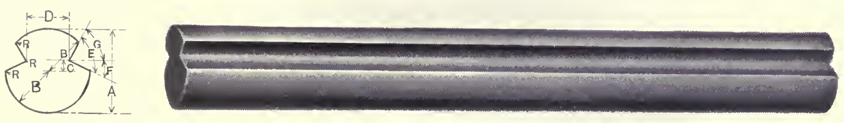
Dimensions of Hard Drawn Copper Trolley Wire

Section of Trolley Wire	Sizes Am. Stan. (B. & S.) Gauge	Sectional Area in Cir. Mils.	Approximate Dimensions, See Cuts Below							
			A	B	C	D	E	F	G	R
Round	0	105,600	.325	.1625	. .	. .	. .	. .	. .	. .
	00	133,200	.365	.1825	. .	. .	. .	. .	. .	. .
	000	168,100	.410	.2045	. .	. .	. .	. .	. .	. .
	0000	211,600	.460	.230	. .	. .	. .	. .	. .	. .
Grooved "American Standard"	00	133,200	.392	.196	.0313	.20	78°	27°	51°	.015
	000	168,100	.430	.215	.0469	.22	78°	27°	51°	.015
	0000	211,600	.482	.241	.0625	.25	78°	27°	51°	.015
Figure 8	00	133,200	.480	.352	.108	.196	. .	. .	. .	. .
	000	168,100	.540	.400	.130	.222	. .	. .	. .	. .
	0000	211,600	.600	.450	.150	.250	. .	. .	. .	. .

Round, Grooved and Figure 8 Copper Trolley Wire

Size B. & S.	Approximate Weight, Pounds		Electrical Conductivity (Minimum)
	Per Mile	Per 1000 Feet	
0	1685	319	Mile—ohm @ 68 degrees Fahr. not to exceed 890.1 equals 98% Matthiesen's Standard
00	2132	404	
000	2690	509	
0000	3386	641	

Round



Grooved

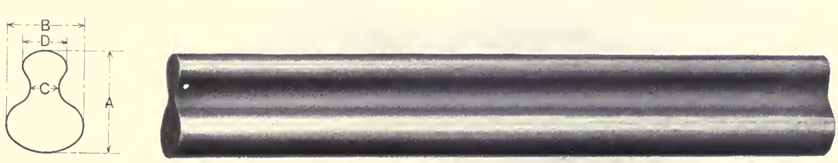


Figure 8

Electric Railway Material

Extra Galvanized W. & M. Telephone and Telegraph Wire

There are three standards of extra galvanized telephone and telegraph wire in general commercial use.

"Extra Best Best" (E.B.B.). Made by improved continuous process and stands highest in conductivity of any telegraph wire with a weight per mile ohm of from 4700 to 5000 pounds. Uniform in quality, pure, tough and pliable. It is largely used by telegraph companies and in railway telegraph service.

"Best Best" (B.B.). Superior to the E.B.B. in mechanical qualities and equal in galvanizing, but of somewhat lower electrical value. Weight per mile ohm, 5600 to 6000 pounds. This grade is used very largely by telephone companies.

"Steel" (or homogeneous metal). More expressly designed for short-line telephone service, where a measure of conductivity can be exchanged for high tensile strength in a light wire. Weight per mile-ohm, 6500 to 7000 pounds.

Properties of Galvanized Telephone and Telegraph Wires

Based on Standard Specifications

Size B. W. G.	Diameter in Mils=d	Area in Circular Mils=d^2	Approximate Weight in Pounds		Approximate Breaking Strain in Pounds			Resistance per Mile (International Ohms) at 68° F. or 20° C.		
			Per 1000 Feet	Per Mile	Ex. B. B.	B. B.	Steel	Ex. B. B.	B. B.	Steel
0	340	115,600	313	1,655	4,138	4,634	4,965	2.84	3.38	3.93
1	300	90,000	244	1,289	3,223	3,609	3,867	3.65	4.34	5.04
2	284	80,656	218	1,155	2,888	3,234	3,465	4.07	4.85	5.63
3	259	67,081	182	960	2,400	2,688	2,880	4.90	5.83	6.77
4	238	56,644	153	811	2,028	2,271	2,433	5.80	6.91	8.01
5	220	48,400	131	693	1,732	1,940	2,079	6.78	8.08	9.38
6	203	41,209	112	590	1,475	1,652	1,770	7.97	9.49	11.02
7	180	32,400	87	463	1,158	1,296	1,389	10.15	12.10	14.04
8	165	27,225	74	390	975	1,092	1,170	12.05	14.36	16.71
9	148	21,904	60	314	785	879	942	14.97	17.84	20.70
10	134	17,956	49	258	645	722	774	18.22	21.71	25.29
11	120	14,400	39	206	515	577	618	22.82	27.19	31.55
12	109	11,881	32	170	425	476	510	27.65	32.94	38.23
13	95	9,025	25	129	310	347	372	37.90	45.16	52.41
14	83	6,889	19	99	247	277	297	47.48	56.56	65.66
15	72	5,184	14	74	185	207	222	63.52	75.68	87.84
16	65	4,225	11	61	152	171	183	77.05	91.80	106.55

Electric Railway Material

W. & M. Telephone Wire

Prices quoted on application

Sizes Birmingham Wire Gauge	Diameter in Decimals of an Inch	Bdls. per Mile	Weight per 1000 Feet in Pounds	Weight per Mile in Pounds	Sizes Birmingham Wire Gauge	Diameter in Decimals of an Inch	Bdls. per Mile	Weight per 1000 Feet in Pounds	Weight per Mile in Pounds
4	0.238	4	153	811	10	0.134	2	49	258
6	0.203	3	112	590	11	0.120	2	39	206
8	0.165	2	74	390	12	0.109	2	32	170
9	0.148	2	60	314	14	0.083	2	19	99

Extra Galvanized Bond Wire

Used for signal bonding on steam roads. Extra B. B. extra galvanized telephone wire is nearly always used for this purpose. Cut and straightened to lengths at a small extra charge. Usually 3 to 5 feet long, and of any gauge number desired.

Extra Galvanized Steel Signal Wire

This wire is used as a connection from a lever or other pulling device to a semaphore signal which is operated mechanically. The two sizes of Extra Galvanized Signal Wire in common use are:

No. 8 B. W. gauge, with an approximate breaking strength of 2350 pounds.

No. 9 B. W. gauge, with an approximate breaking strength of 1900 pounds.

The wire is made especially to meet the important requirements of this service. It is extra galvanized, and of a quality that possesses high strength and as low elongation as is practicable without sacrificing toughness. The coils are 5 feet in diameter and approximately one-half mile in length without welds or joints.

Steel Strand for Guying Poles and for Span Wire

Galvanized or Extra Galvanized

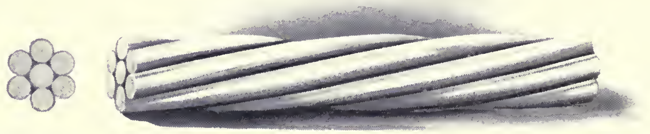
Diameter in Inches	Approximate Weight per 1000 Feet Pounds	Approximate Strength in Pounds	Diameter in Inches	Approximate Weight per 1000 Feet Pounds	Approximate Strength in Pounds
1/2	510	8500.	7/32	95	1800.
7/16	415	6500.	3/16	75	1400.
3/8	295	5000.	5/32	55	900.
5/16	210	3800.	1/8	32	500.
1/4	125	2300.	3/32	20	400.

This strand is used chiefly for guying poles and smoke stacks, for supporting trolley wire, and for operating railroad signals.

For overhead catenary construction suspending trolley wire, the special grades of strand are considered preferable because they possess greater strength and toughness.

Electric Railway Material

Extra Galvanized Special Strands



We manufacture three special grades of Extra Galvanized Strand which will meet all requirements for durability, strength, toughness and light weight.

Extra Galvanized Siemens-Martin Strand.

Extra Galvanized High Strength (crucible steel) Strand.

Extra Galvanized Extra High Strength (plow steel) Strand.

Strands of all three grades are composed of seven wires each, and they have a very heavy coating of galvanizing, which insures long life.

Minimum Values

Extra Galvanized Siemens-Martin Strand					Extra Galvanized High Strength Strand					Extra Galvanized Extra High Strength Strand				
Diameter in Inches	Actual Breaking Strength in Pounds	List Prices per 100 Feet	Elastic Limit Per Cent.	Per Cent. Elongation in 24 Inches	Diameter in Inches	Actual Breaking Strength in Pounds	List Prices per 100 Feet	Elastic Limit Per Cent.	Per Cent. Elongation in 24 Inches	Diameter in Inches	Actual Breaking Strength in Pounds	List Prices per 100 Feet	Elastic Limit Per Cent.	Per Cent. Elongation in 24 Inches
5/8	19,000	$4.35	50	10.0	5/8	25,000	$6.25	55	6	5/8	42,500	$8.75	60	4
1/2	11,000	2.80	50	10.0	1/2	18,000	3.95	55	6	1/2	27,000	5.50	60	4
7/16	9,000	2.30	50	10.0	7/16	15,000	3.45	55	6	7/16	22,500	4.60	60	4
3/8	6,800	1.80	50	10.0	3/8	11,500	2.70	55	6	3/8	17,250	3.55	60	4
5/16	4,860	1.35	50	10.0	5/16	8,100	2.10	55	6	5/16	12,100	2.70	60	4
9/32	4,380	1.10	50	10.0	9/32	7,300	1.75	55	6	9/32	10,900	2.10	60	4
1/4	3,060	1.00	50	10.0	1/4	5,100	1.50	55	6	1/4	7,600	1.90	60	4
3/16	2,000	.85	50	10.0	3/16	3,300	1.30	55	6	3/16	4,900	1.60	60	4
1/8	900	.55	50	10.0	1/8	1,500	.80	55	6	1/8	2,250	1.05	60	4
Special 5/16	6,000	1.35												

Messenger Strand The heavy encased telephone cables are not in themselves sufficiently strong, without an unusual deflection, to safely withstand the strain incident to stringing these cables between poles at considerable distances apart. It is common practice now to stretch from pole to pole, with very little sag, 5/16-inch diameter Extra Galvanized Siemens-Martin Strand; or Extra Galvanized High Strength Strand of 3/8-inch or 7/16-inch diameter, and from this messenger strand the heavy telephone cable is suspended by means of clips, wire, cord, or marline at short intervals. The messenger strand thus sustains most of the stress due to weight of cable, wind or ice load. We have mentioned the sizes and qualities now generally employed by

Electric Railway Material

the largest telephone companies. The Extra Galvanized Extra High Strength Strand, while affording the greatest strength for its weight, is naturally stiff and springy and not so easy to fasten. The so-called common galvanized strand should never be used for messenger lines, as it does not possess the requisite strength and uniform toughness of the special grades of steel.

Catenary Method of Supporting Trolley Wire

In the ordinary electric railway overhead construction, the copper trolley wire dips and sags between the supporting points, which are opposite poles, and from 100 to 125 feet apart. The catenary method of carrying the trolley wire consists of one or more messenger strands stretched over the center of the tracks. Every few feet along the messenger strand are pendant hangers that clamp on the trolley wire and retain it in a rigid, straight horizontal line, an especially desirable feature for the operation of electric cars at high speed. The catenary construction also makes it possible to space the poles at greater distances apart, but this necessarily causes great tension on the messenger strand and poles. The common galvanized strand is not suitable for this work. The selection of the best size and quality of strand depends upon the length of span, the deflection of the messenger strand, and the weight of the trolley wire. In general, however, for a single messenger strand carrying a 4/0 copper trolley wire, we would recommend the following:

For spans 125 to 150 feet, ⅜-inch or $\frac{7}{16}$-inch diameter Extra Galvanized Siemens-Martin Strand.

For longer spans up to 225 feet, ⅜-inch or $\frac{7}{16}$-inch Extra Galvanized High Strength Strand.

These two grades have been found the best for catenary work.

Our ¼-inch or $\frac{5}{16}$-inch diameter Extra Galvanized Siemens-Martin Strand is usually employed for "pull-off" strands.

Lightning Protection for Transmission Lines

In erecting high-tension current transmission lines on tall steel towers, it is customary to stretch between the highest points of the towers a ⅜-inch diameter Extra Galvanized Siemens-Martin Strand, known as an "overhead ground wire."

Long Span in High-tension Current Transmission Line

Long spans cannot always be made with copper cables, because hard drawn copper has a strength of only 65,000 pounds per square inch. Where it is necessary to cross over rivers, lakes and bays with power transmission lines, the current may be conducted through an extra galvanized strand of one of the three special grades of steel above described, of such size and strength as will show a safety factor of at least five.

Electric Railway Material

Properties of Special Grades of Extra Galvanized Special Strands

Diameter of Strand, Inches	Number of Wires in Strand	Strength S. M. Strand Tons	Strength Crucible Strand Tons	Strength Plow Strand Tons	Approximate Weight per Foot Pounds
1½	61	55	91.5	121	4.75
1⅜	61	45.5	76	100	3.95
1¼	37	38	63.5	85	3.30
1⅛	37	32.5	54	72	2.62
1	37	25.5	43.7	60	2.25
⅞	19	19	32	45	1.70
¾	19	14.2	23.7	35	1.25
⅝	19	10	16.5	23.5	.81

American Railway Fence

We make a specialty of fence for right-of-way of steam and electric roads, furnishing designs for this particular purpose. Our woven wire fence has been adopted as standard by practically every steam and electric road in the United States. We furnish fence particularly adapted to locality in which it is to be used, making a close study of conditions and supplying fence, giving the greatest possible efficiency at minimum cost. Write for descriptive catalogue and prices.

Pole Steps

Plain and Extra Galvanized

For the use of electric light, street railway and telephone companies

Sizes	Approximate Weight per 100 Pole Steps		Sizes	Approximate Weight per 100 Pole Steps	
	Plain	Galvanized		Plain	Galvanized
8 x ⅝ inch	73½ pounds	75 pounds	8½ x 9/16 inch	58 pounds	61 pounds
9 x ⅝ inch	78 pounds	81 pounds	9 x 9/16 inch	62 pounds	65 pounds
10 x ⅝ inch	85 pounds	88 pounds	10½ x 9/16 inch	71 pounds	74 pounds
10½ x ⅝ inch	89 pounds	93 pounds	9 x ½ inch	51 pounds	54 pounds

The above are made with regular spike and button heads. Lengths given are measurements over all. Each step carefully threaded with screw thread. Special shapes or lengths of heads made to order. A keg of pole steps weighs about 200 pounds. Prices on application.

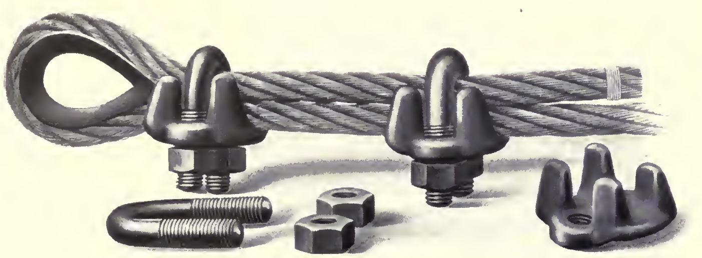
Electric Railway Material

"Crosby" Wire Rope Clip

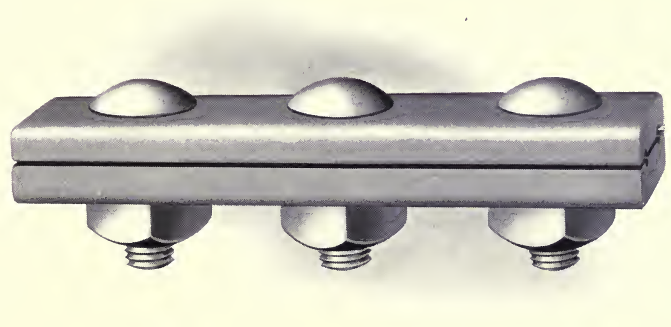
Light, durable and convenient. Easily applied. These are galvanized drop-forged clips that securely hold wire rope or strand.

List Prices

Inch	Price	Inch	Price	Inch	Price	Inch	Price	Inch	Price	Inch	Price
¼	$ .35	7/16	$ .45	¾	$ .65	1⅛	$ .95	1½	$1.50	2	$ 7.50
5/16	.35	½	.45	⅞	.75	1¼	1.10	1⅝	3.50	2¼	9.50
⅜	.40	⅝	.55	1	.85	1⅜	1.25	1¾	5.50	2½	11.50



"Crosby" Wire Rope Clip



Galvanized Three-bolt Strand Clamped

This is known as the standard A. T. & T. Co. hot galvanized rolled steel strand clamp or guy clamp, made from open hearth bar steel. Will hold any size of strand from ¼-inch to ½-inch diameter.

Prices on application.

Electric Railway Material

Round Cotton-covered Magnet Wire

Advances on Coarse Sizes

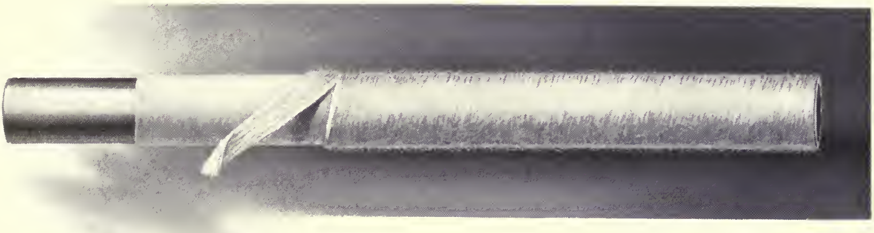
Sizes American Standard (B. & S.) Gauge	Single Cotton-covered			Double Cotton-covered			Triple Cotton-covered		Approximate Quantity on Reels Pounds	Number of Reel
	List Number	Advances Over Base per 100 Pounds	Approximate Pounds per 1000 Feet	List Number	Advances Over Base per 100 Pounds	Approximate Pounds per 1000 Feet	List Number	Advances Over Base per 100 Pounds		
0	5000	Base	321	5100	Base	322	6000	Base	150	321
1	5001	Base	254	5101	Base	256	6001	Base	150	313
2	5002	Base	202	5102	Base	203	6002	Base	150	313
3	5003	Base	160	5103	Base	161	6003	Base	150	313
4	5004	Base	127	5104	Base	128	6004	Base	150	313
5	5005	Base	101	5105	Base	101.5	6005	Base	150	313
6	5006	Base	80.1	5106	Base	80.6	6006	Base	150	313
7	5007	$0.25	63.6	5107	$0.25	64.1	6007	$0.25	150	313
8	5008	.50	50.4	5108	.75	50.9	6008	.75	150	313
9	5009	.75	40.1	5109	1.25	40.4	6009	1.25	150	313
10	5010	1.00	31.9	5110	1.75	32.1	6010	2.00	150	313
11	5011	1.50	25.3	5111	2.25	25.5	6011	2.75	150	313
12	5012	2.00	20.1	5112	2.75	20.3	6012	3.50	150	313
13	5013	2.50	16	5113	3.50	16.2	6013	4.75	150	313
14	5014	3.00	12.7	5114	4.25	12.9	6014	6.00	150	313
15	5015	3.50	10.1	5115	5.00	10.3	6015	7.25	150	313
16	5016	4.00	7.99	5116	5.75	8.15	6016	8.50	50	338
17	5017	4.50	6.36	5117	6.75	6.51	6017	10.00	50	338
18	5018	5.25	5.05	5118	7.75	5.19	6018	11.50	50	338
19	5019	6.00	4.04	5119	8.75	4.15	6019	13.00	15	343

Properties of Coarse Sizes

Sizes American Standard (B. & S.) Gauge	Diameter Inches	Allowable Variation Either Way in Per Cent.	Rated Area in Cir. Mils.	Single Cotton-covered Approximate Values		Double Cotton-covered Approximate Values	
				Outside Diameter Inches	Feet per Pound	Outside Diameter Inches	Feet per Pound
0	0.3249	½ of 1	105,625	.333	3.1	.339	3.1
1	.2893	½ of 1	83,694	.297	3.9	.303	3.9
2	.2576	½ of 1	66,358	.266	5.0	.272	4.9
3	.2294	¾ of 1	52,624	.237	6.2	.243	6.2
4	.2043	¾ of 1	41,738	.212	7.8	.218	7.8
5	.1819	¾ of 1	33,088	.190	9.9	.196	9.9
6	.1620	¾ of 1	26,244	.170	12.5	.176	12.4
7	.1443	¾ of 1	20,822	.152	15.7	.158	15.6
8	.1285	1	16,512	.136	19.8	.142	19.6
9	.1144	1	13,087	.121	24.9	.125	24.7
10	.1019	1	10,384	.108	31.4	.113	31.1
11	.0907	1	8,226	.097	39.5	.102	39.1
12	.0808	1¼	6,528	.087	49.6	.092	49.2
13	.0720	1¼	5,184	.078	62.5	.083	61.7
14	.0641	1¼	4,108	.070	78.6	.075	77.5
15	.0571	1½	3,260	.063	98.9	.068	97
16	.0508	1½	2,580	.056	125	.060	122
17	.0453	1½	2,052	.050	157	.054	153
18	.0403	1½	1,624	.045	198	.050	192
19	.0359	1¾	1,288	.041	248	.045	240

Electric Railway Material

Asbestos and Single Cotton-covered



Round Asbestos and S. C. C. Magnet Wire

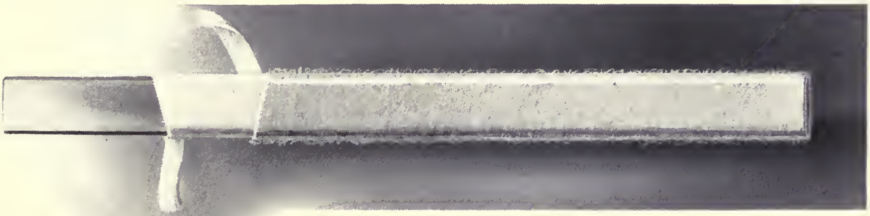
Order by List Numbers

Sizes American Standard (B. & S.) Gauge	List Number for Asbestos and Single Cotton Cover	Approximate Pounds per 1000 Feet	Approximate Diameter Over Insulation Inches	Approximate Quantity on Reels Pounds	Round Asbestos and Single Cotton-covered Advances Over Base per 100 Pounds	Round Asbestos and Double Cotton-covered Advances Over Base per 100 Pounds Special	Shipped on Reels Number
0000	5440	. .	.482	150	Base	Base	321
000	5430	. .	.432	150	Base	Base	321
00	5420	. .	.387	150	Base	Base	321
0	5400	325	.347	150	Base	Base	321
1	5401	258	.311	150	Base	Base	313
2	5402	205	.280	150	Base	Base	313
3	5403	163	.251	150	Base	Base	313
4	5404	130	.226	150	Base	Base	313
5	5405	103	.204	150	Base	Base	313
6	5406	82	.184	150	Base	Base	313
7	5407	66	.166	150	$0.25	$0.25	313
8	5408	52	.150	150	.75	.75	313
9	5409	42	.136	150	1.25	1.25	313

A very thin asbestos tape is first applied to the wire. This tape is strong and flexible and uniform in texture. It serves as an excellent fire protection. Over this asbestos is wound one or sometimes two covers of cotton. This magnet wire is used largely for railway motor purposes.

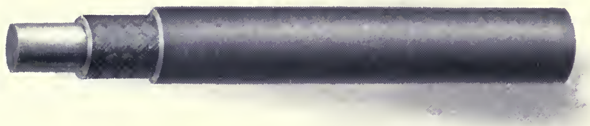
Square or Rectangular Magnet Wire

All Size



Double Cotton-covered

Reliance Weatherproof Wire

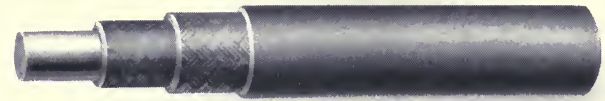


Solid Copper Conductor—Double Braid—Black Finish

Advances on Weatherproof Wire

Sizes Amer. Stand. (B. & S.) Gauge	Diameter Inches Bare Wire	Area Circular Mils	List Number	Advance Over Base per 100 Pounds	Approx. Weights: Pounds per 1000 Feet	Approx. Weights: Pounds per Mile	Standard Packages Approx. Amount	Shipped on Reel Number
0000	460.0	211600	2040	$ .50	723	3,817	2,400 ft.	315
000	409.6	167772	2030	.50	587	3,098	2,500 ft.	315
00	364.8	133079	2020	.50	467	2,467	3,200 ft.	315
0	325.0	105625	2000	.50	377	1,989	4,300 ft.	315
1	289.3	83694	2001	.50	294	1,553	1,000 ff.	302
2	257.6	66358	2002	.50	239	1,264	1,300 ft.	302
3	229.4	52624	2003	.50	185	977	1,600 ft.	302
4	204.3	41738	2004	.50	151	795	2,100 ft.	302
5	181.9	33088	2005	.50	122	646	2,500 ft.	322
6	162.0	26244	2006	.50	100	529	3,400 ft.	322
8	128.5	16512	2008	.50	66	349	5,000 ft.	322
9	114.4	13087	2009	1.50	54	283	6,000 ft.	322
10	101.9	10384	2010	1.50	46	241	35-50 lbs.	Coils
12	80.8	6528.6	2012	2.50	30	158	25-40 lbs.	Coils
14	64.1	4108.8	2014	3.50	20	107	25-40 lbs.	Coils
16	50.8	2580.6	2016	4.50	16	83	20-30 lbs.	Coils
18	40.3	1624.1	2018	5.50	12	64	20-30 lbs.	Coils

Reliance Weatherproof Wire



Solid Copper Wire—Triple Braid—Black Finish

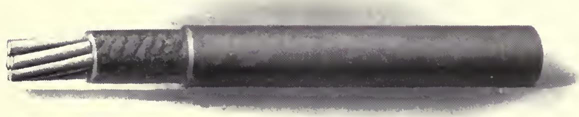
National Electric Code Wire

Order by List Numbers

Sizes American Standard (B. & S.) Gauge	Minimum Thickness of Insulation Inches	List Number	Advance Over Base per 100 Pounds	Approx. Weights: Pounds per 1000 Feet	Approx. Weights: Pounds per Mile	Standard Packages Approx. Amount	Shipped on Reel Number
0000	.0781	2140	Base	767	4,050	2,400 ft.	315
000	.0781	2130	Base	629	3,320	2,500 ft.	315
00	.0781	2120	Base	502	2,650	3,200 ft.	315
0	.0781	2100	Base	407	2,150	4,300 ft.	315
1	.0781	2101	Base	316	1,670	1,000 ft.	302
2	.0625	2102	Base	260	1,370	1,300 ft.	302
3	.0625	2103	Base	199	1,050	1,600 ft.	302
4	.0625	2104	Base	164	865	2,100 ft.	302
5	.0625	2105	Base	135	710	2,500 ft.	322
6	.0625	2106	Base	112	590	3,400 ft.	322
8	.0469	2108	Base	75	395	5,000 ft.	322
9	.0469	2109	$1.00	62	325	6,000 ft.	322
10	.0469	2110	1.00	53	280	35-50 lbs.	Coils
12	.0469	2112	2.00	35	185	25-40 lbs.	Coils
14	.0469	2114	3.00	25	130	25-40 lbs.	Coils
16	.0469	2116	4.00	20	105	20-30 lbs.	Coils
18	.0469	2118	5.00	16	85	20-30 lbs.	Coils

The above standard weights have been adopted because wires having those weights endure longest in service and suit the largest number of customers. Slight variations should be expected in practice.

Reliance Weatherproof Cables



Stranded Copper Conductors—Double Braid—Black Finish

Order by List Numbers

Size	No. and Diameter of Wires in Strand Inches	Diameter Bare Strand Inches	List Number	Advance Over Base per 100 Pounds	Approximate Weights	
					Pounds per 1000 Feet	Pounds per Mile
2,000,000	91 x .1482	1.6302	2250	$0.75	6690	35,323
1,750,000	91 x .1386	1.5246	2251	.75	5894	31,119
1,500,000	91 x .1284	1.4124	2252	.75	5098	26,915
1,250,000	91 x .1172	1.2892	2253	.75	4264	22,516
1,000,000	61 x .1280	1.1520	2254	.75	3456	18,246
900,000	61 x .1215	1.0935	2257	.75	3127	16,513
800,000	61 x .1145	1.0305	2259	.75	2799	14,779
750,000	61 x .1109	.9981	2260	.75	2635	13,913
700,000	61 x .1071	.9639	2261	.75	2471	13,046
600,000	61 x .0992	.8928	2263	1.00	2093	11,052
500,000	37 x .1162	.8134	2265	.75	1765	9,318
450,000	37 x .1103	.7721	2267	.75	1601	8,452
400,000	37 x .1040	.7280	2268	.75	1436	7,584
350,000	37 x .0973	.6811	2269	1.00	1248	6,589
300,000	19 x .1257	.6285	2270	.75	1083	5,721
250,000	19 x .1147	.5735	2271	.75	907	4,788
0000	19 x .1055	.5275	2240	.75	745	3,935
000	19 x .0940	.4700	2230	1.00	604	3,190
00	7 x .1378	.4134	2220	.75	482	2,544
0	7 x .1228	.3684	2200	.75	388	2,051
1	7 x .1093	.3279	2201	.75	303	1,599
2	7 x .0973	.2919	2202	1.00	246	1,301
3	7 x .0867	.2601	2203	1.00	190	1,004
4	7 x .0772	.2316	2204	1.50	155	820
5	7 x .0687	.2061	2205	1.50	126	668
6	7 x .0612	.1836	2206	2.00	103	544
8	7 x .0485	.1455	2208	2.50	68	359

Reliance Weatherproof Cables

Stranded Copper Conductors—Triple Braid—Black Finish

National Electrical Code Wire

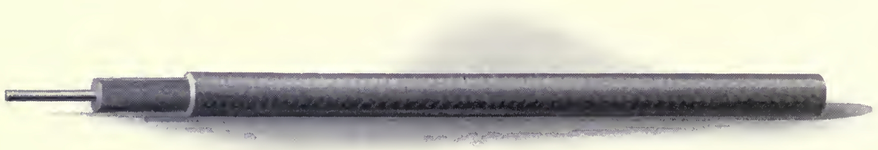
Advances on Weatherproof Cables

Size	Minimum Thickness of Insulation Inches	List Number	Advance Over Base per 100 Pounds	Approximate Weights		Standard Packages Approx. Amount Feet	Shipped on Reel Number
				Pounds per 1000 Feet	Pounds per Mile		
2,000,000	.1250	2350	$0.25	7008	37,000	600	324
1,750,000	.1250	2351	.25	6193	32,700	700	324
1,500,000	.1250	2352	.25	5380	28,400	850	324
1,250,000	.1250	2353	.25	4508	23,800	1000	324
1,000,000	.1250	2354	.25	3674	19,400	1320	324
900,000	.1094	2357	.25	3332	17,600	1320	324
800,000	.1094	2359	.25	2992	15,800	1320	324
750,000	.1094	2360	.25	2822	14,900	1320	333
700,000	.1094	2361	.25	2650	14,000	1320	333
600,000	.1094	2363	.50	2235	11,800	1320	333
500,000	.1094	2365	.25	1894	10,000	1320	333
450,000	.0938	2367	.25	1724	9,100	1320	333
400,000	.0938	2368	.25	1553	8,200	1320	333
350,000	.0938	2369	.50	1345	7,100	2640	333
300,000	.0938	2370	.25	1174	6,200	2640	333
250,000	.0938	2371	.25	985	5,200	2640	333
0000	.0781	2340	.25	800	4.220	2000	315
000	.0781	2330	.50	653	3,450	2000	315
00	.0781	2320	.25	522	2,760	2640	315
0	.0781	2300	.25	424	2,240	2640	315
1	.0781	2301	.25	328	1,735	1000	302
2	.0625	2302	.50	270	1,425	1300	302
3	.0625	2303	.50	206	1,090	1600	302
4	.0625	2304	1.00	170	900	2100	302
5	.0625	2305	1.00	140	740	3000	322
6	.0625	2306	1.50	115	610	3400	322
8	.0469	2308	2.00	78	410	4000	322

Electric Railway Material
Rubber-covered Wires and Cables

We manufacture rubber insulated electrical wires and cables of all descriptions and for all purposes, leaded or armored. These are fully described in our recent "Electrical Wires and Cables" catalogue.

Globe rubber insulation wires and cables.
Crown rubber insulation wires and cables.
High grade, 30 per cent para and special insulated wires and cables.
Telephone wires and cables.
Signal wires and cables.
Car cables.
Mining machine cables.
Packing house cord.
Elevator lighting cables.
Elevator control cables.
Theatre or stage cables.
Border light cables.
Deck cables.



Kinds of Rubber Insulation

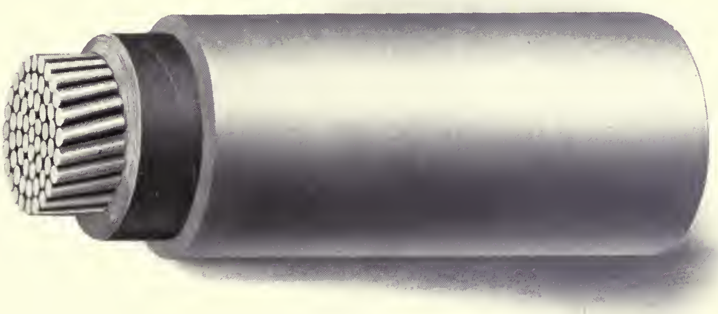
We make three standard grades of rubber compound for rubber-covered conductors: *Globe*, or ordinary compound; *Crown*, or intermediate compound; and a *High Grade Thirty Per Cent* Compound. In addition, we insulate wire to any specifications covering particular requirements such as 20 or 40 per cent rubber compounds.

Globe Rubber This is regularly furnished on wires and cables for 600-volt National Electrical Code requirements. It can however be used for potentials as high as 2500 volts, if the service conditions be favorable to rubber, or if the conductor be lead encased.

Crown Rubber This rubber has better physical properties than the Globe, is more durable, stronger and has a higher factor of safety. It is a high grade compound for all National Electrical Code requirements and can be recommended for service conditions in which the working pressure is 7000 volts or under.

High Grade Thirty Per Cent Rubber Compound Contains only the best grade of pure para rubber, and is used for high voltage circuits. This makes an unsurpassed dielectric for all high voltages and for exacting service conditions; it has great strength and elasticity, high insulation qualities and long life. All of these compounds make solid black rubber.

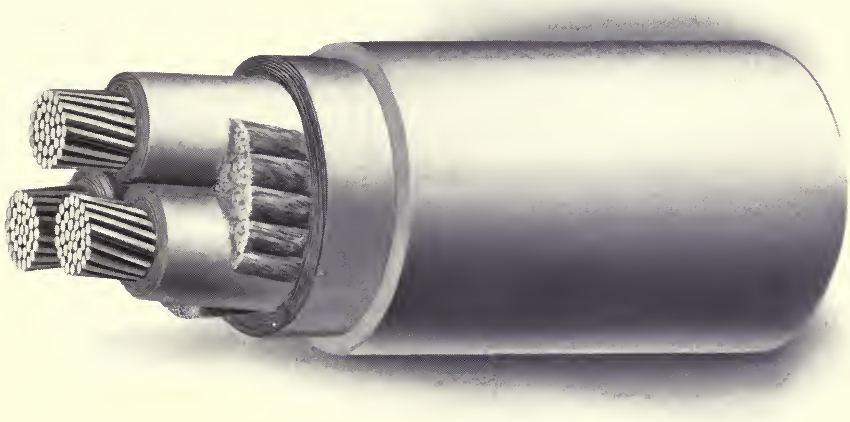
Electric Railway Material
Paper-insulated Lead-sheathed Cables



For many years past we have manufactured large quantities of paper cables, single and multiple conductor. Our factory equipment is unexcelled for making this class of material to the most exacting specifications.

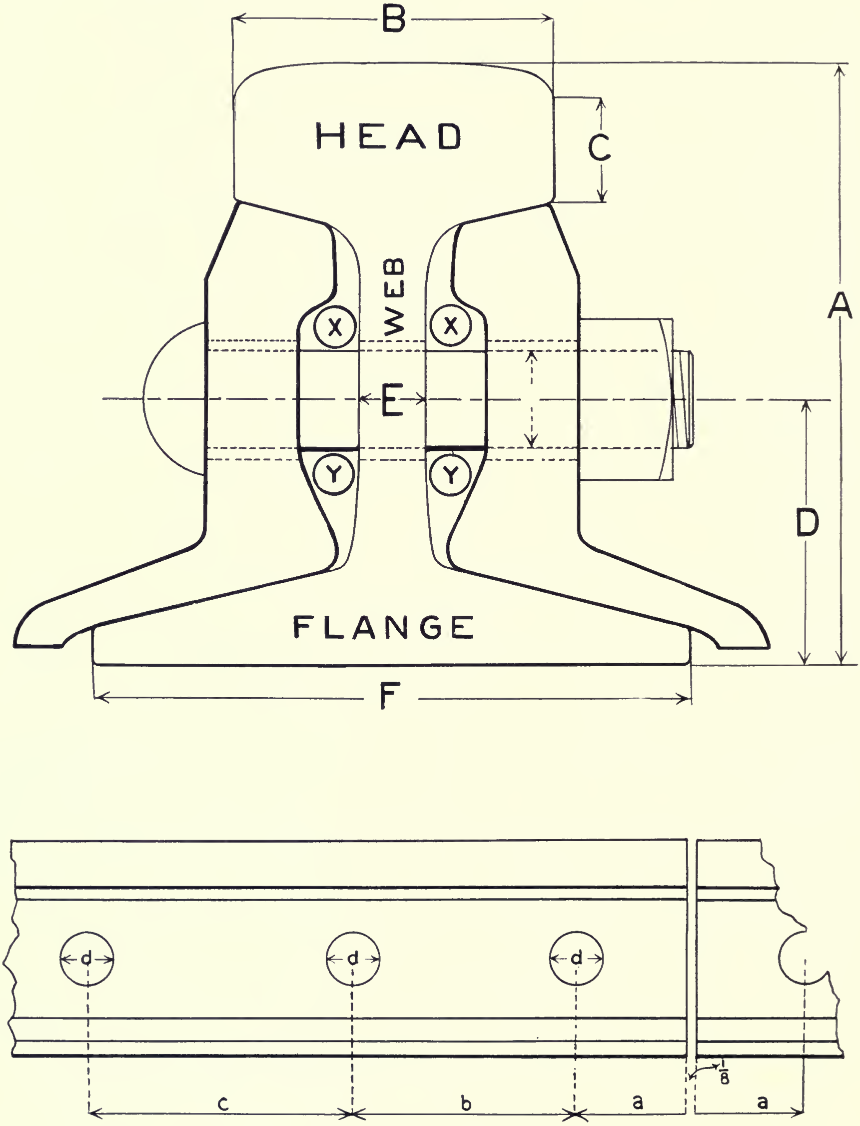
Prices quoted on application.

Varnished Cambric Cables



We also manufacture large quantities of varnished cambric cable and submarine cable of every class, for street railways and electric light and power plants. Inquiries solicited.

Engineering Data



T-rail Section and Drilling

Engineering Data

Properties and Dimensions of T-Rails

As made by the Carnegie Steel Company and the Illinois Steel Company

A. S. C. E. Sections

Weight of Rail per Yard in Pounds	Dimensions of Rail Sections in Inches STANDARD T-RAILS (See opposite page)						Drilling of Rails in Inches STANDARD with Carnegie Steel Co. and Illinois Steel Co. as Shown in Their Rail Catalogue				Section of Rail in Square Inches	Ohmic Resistance of One Rail per 1000 Feet Assuming it to Equal 12 Times that of Copper No. Joints 68° F.
	A	B	C	D	E	F	a	b	c	d		
8	1 9/16	13/16	3/16	11/16	5/32	1 9/16	2	4	..	1/2	0.784	.12454
16	2 3/8	1 11/64	1/4	1 7/128	7/32	2 3/8	2	4	..	5/8	1.57	.06227
20	2 5/8	1 11/32	5/16	1 11/64	1/4	2 5/8	2	4	..	5/8	1.96	.049808
30	3 1/8	1 11/16	11/32	1 25/64	21/64	3 1/8	2	4	..	3/4	2.94	.033212
40	3 1/2	1 7/8	15/32	1 71/128	25/64	3 1/2	2 1/2	5	..	7/8	3.92	.024908
45	3 11/16	2	1/2	1 41/64	27/64	3 11/16	2 1/2	5	..	7/8	4.42	.022170
50	3 7/8	1 1/8	9/16	1 23/32	7/16	3 7/8	2 1/2	5	..	1	4.90	.019925
55	4 1/16	2 1/4	9/16	1 103/128	15/32	4 1/16	2 1/2	5	..	1	5.39	.018114
60	4 1/4	2 3/8	5/8	1 115/128	31/64	4 1/4	2 1/2	5	..	1	5.88	.016606
65	4 7/16	2 13/32	11/16	1 31/32	1/2	4 7/16	2 1/2	5	..	1	6.37	.01538
70	4 5/8	2 7/16	3/4	2 3/64	33/64	4 5/8	2 1/2	5	6	1	6.86	.014233
75	4 13/16	2 15/32	3/4	2 15/128	17/32	4 13/16	2 1/2	5	6	1	7.35	.01336
80	5	2 1/2	13/16	2 3/16	35/64	5	2 1/2	5	6	1	7.84	.012454
85	5 3/16	2 9/16	7/8	2 17/64	9/16	5 3/16	2 1/2	5	6	1	8.33	.01185
90	5 3/8	2 5/8	15/16	2 45/128	9/16	5 3/8	2 1/2	5	6	1	8.82	.011070
95	5 9/16	2 11/16	15/16	2 55/128	9/16	5 9/16	2 1/2	5	6	1	9.31	.01053
100	5 3/4	2 3/4	1	2 65/128	9/16	5 3/4	2 1/2	5	6	1	9.80	.009963
110	6 1/8	2 7/8	1 1/16	2 43/64	37/64	6 1/8	2 1/2	5	6	1	10.80	.009057

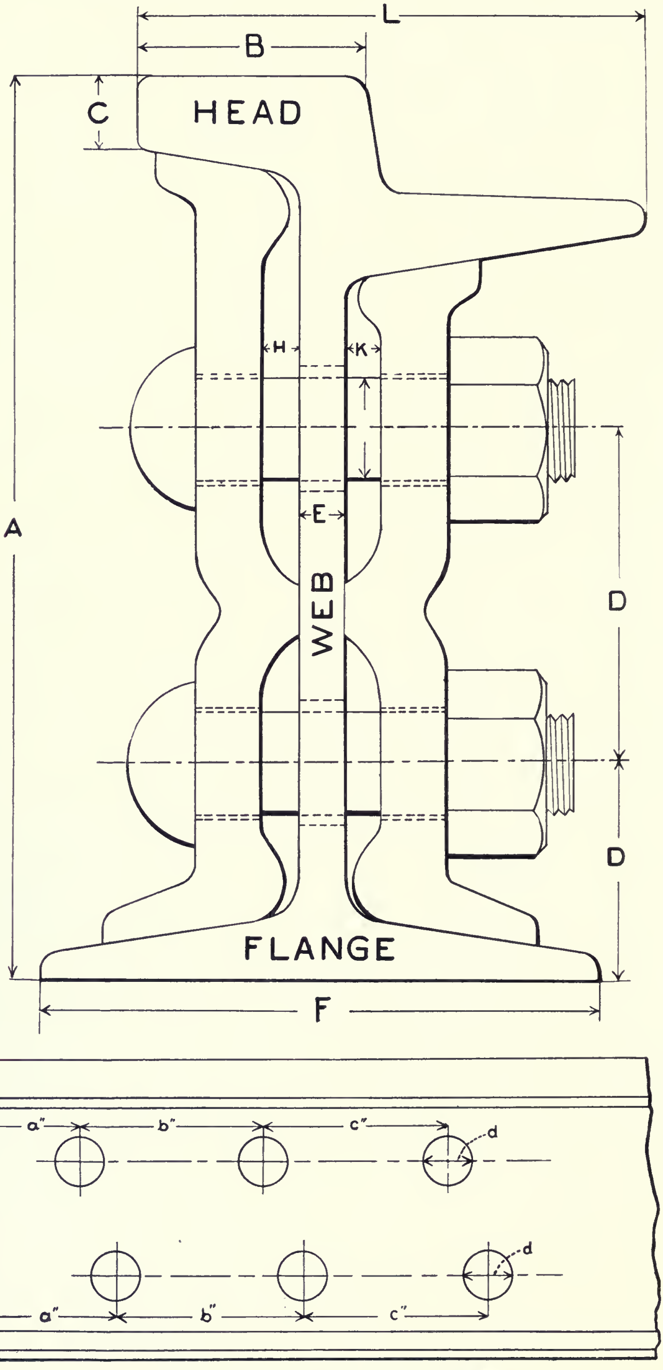
Series Type "A"

60	4 1/2	2 1/4	5/8	2 17/64	15/32	4	2 1/2	5	..	1	5.88	.016606
70	4 3/4	2 3/8	3/4	2 13/32	1/2	4 1/4	2 1/2	5	6	1	6.86	.014233
80	5 1/8	2 1/2	13/16	2 9/16	33/64	4 5/8	2 1/2	5	6	1 1/8	7.84	.012454
90	5 5/8	2 9/16	13/16	2 29/32	9/16	5 1/8	2 1/2	5	6	1 1/4	8.82	.011070
100	6	2 3/4	7/8	2 15/16	9/16	5 1/2	2 1/2	5	6	1 1/4	9.80	.009963

Series Type " B "

60	4 3/16	2 1/8	11/16	1 29/32	31/64	3 11/16	2 1/2	5	..	1	5.88	.016606
70	4 35/64	2 3/8	3/4	2 7/128	33/64	4 3/64	2 1/2	5	6	1	6.86	.014233
80	4 15/16	2 7/16	7/8	2 15/64	35/64	4 7/16	2 1/2	5	6	1 1/8	7.84	.012454
90	5 17/64	2 9/16	15/16	2 11/32	9/16	4 49/64	2 1/2	5	6	1 1/4	8.02	.011070
100	5 41/64	2 21/32	1	2 65/128	9/16	5 9/64	2 1/2	5	6	1 1/4	9.80	.009963

NOTE—The two tables, Series Type "A" and Series Type " B " represent T-rail sections proposed by the Committee on Standard Rail and Wheel Sections for adoption as " Recommended Practice of the American Railway Association."



Girder Rail Section and Drilling

Engineering Data

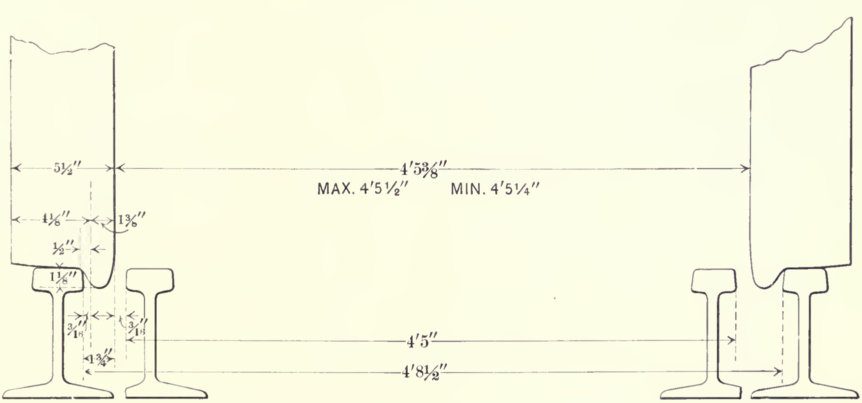
Properties and Dimensions of Girder Rails in Most Common Use

These girder rails are made by the Lorain Steel Company and they are shown in the Lorain Catalogue No. 16.

Section No. and Size of Rail in Pounds per Yards	Dimensions of Girder Rail Sections in Inches (See opposite page)							Standard Drilling of Rails in Inches							Sectional Area of Rail in Inches	Section of Rail in Circular Mils. Ratio Steel to Copper 1:12
	A	B	C	D	D′	E	F	Diam. (d) of Holes	Upper Row of Holes a	Upper Row of Holes b	Upper Row of Holes c	Lower Row of Holes a′	Lower Row of Holes b′	Lower Row of Holes c′		
73	7	$2\frac{1}{8}$	$\frac{1}{2}$	$2\frac{53}{64}$	...	$\frac{11}{32}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{2}$	4	4	...	...	...	7.16	758,864
90	$8\frac{25}{32}$	$2\frac{1}{4}$	$\frac{9}{16}$	$2\frac{3}{32}$	$3\frac{1}{4}$	$\frac{11}{32}$	$5\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{2}$	5	5	$3\frac{1}{2}$	5	5	8.82	935,825
95	7	3	$\frac{11}{16}$	$3\frac{15}{64}$	...	$\frac{17}{32}$	6	$1\frac{1}{4}$	$2\frac{1}{4}$	4	4	...	...	...	9.31	987,880
116	7	3	$\frac{1}{2}$	$2\frac{19}{32}$	...	$\frac{1}{2}$	$5\frac{1}{2}$	$1\frac{3}{16}$	$2\frac{1}{2}$	4	4	...	...	...	11.39	1,206,000
129	9	$2\frac{3}{4}$	$\frac{7}{16}$	$2\frac{3}{16}$	3	$\frac{1}{2}$	6	$1\frac{1}{4}$	$2\frac{1}{2}$	5	5	$3\frac{1}{2}$	5	5	12.66	1,341,000

Rail Joints

It is generally concluded by railway engineers (a) that the spacing of rails with open joints is unnecessary in paved streets; (b) that it is best not to stagger rail joints subjected to heavy traffic; and (c) that in making a joint, the parts of rail and splice bar brought into contact should be cleaned of scale and rust, that the bolts should not be overstrained when fully drawn up, and sledging should be reduced to a minimum.



M. C. B. Track and Wheel Gauge

Engineering Data

To Find the Degree or Radius of Railway Curve

(From the Roadmasters' Assistant)

Stretch taut a 50-foot tape line on the inner side of the rail and measure the perpendicular distance (which is the "middle ordinate") from the center of the tape line to the inner edge of the rail.

The radius and degree of the curve corresponding to this middle ordinate may then be found in the following table:

Degrees	Radius in Feet	Middle Ordinate in Inches	Degrees	Radius in Feet	Middle Ordinate in Inches	Degrees	Radius in Feet	Middle Ordinate in Inches
30	11,490	.22	7°	819	4.57	14°	410	9.17
1°	5,730	.66	8°	717	5.24	15°	383	9.80
2°	2,865	1.32	9°	637	5.89	16°	359	10.49
3°	1,910	1.97	10°	574	6.54	17°	338	11.11
4°	1,433	2.63	11°	522	7.20	18°	320	11.78
5°	1,146	3.28	12°	478	7.87	19°	303	12.41
6°	955	3.94	13°	442	8.51	20°	288	13.06

To Ascertain the Radius Corresponding to any Degree

Divide 5730 (the radius of a 1° curve) by the degree of the curve under consideration.

To Determine the Elevation of the Outer Rail on Curves

Stretch a line between two points 54 feet apart, on the running side of the outer rail, and the distance from the center of this line to the rail will give the elevation required.

Table of Middle Ordinates for Bending Rails to be Laid on Curves

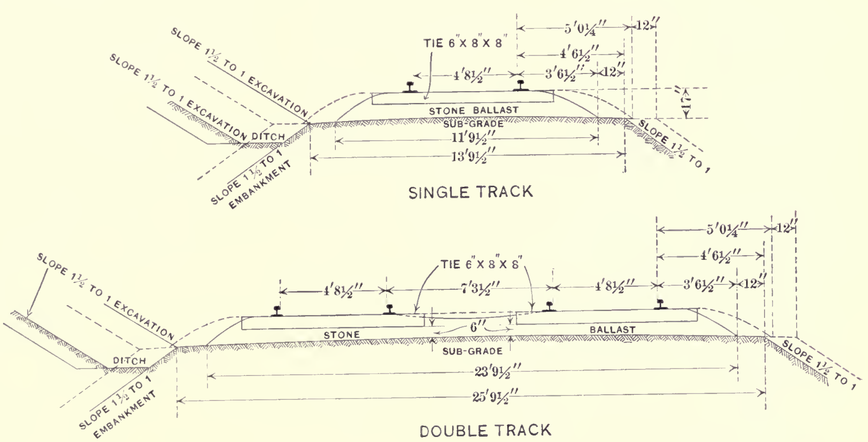
Deflection Angle Degrees	Radius Feet	Length of Rails in Feet								
		30	28	26	24	22	20	18	16	14
		Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
.5	11,460	.120	.096	.072	.060	.048	.048	.036	.024	.024
1.	5,730	.240	.192	.156	.132	.108	.096	.072	.060	.048
1.5	3,820	.348	.312	.252	.216	.192	.156	.120	.096	.072
2.	2,865	.456	.408	.348	.300	.252	.204	.168	.132	.096
2.5	2,292	.588	.516	.444	.372	.324	.264	.216	.168	.120
3.	1,910	.696	.612	.528	.444	.372	.312	.264	.204	.144
3.5	1,637	.840	.732	.624	.516	.444	.372	.300	.240	.180
4.	1,433	.948	.828	.720	.600	.504	.420	.348	.276	.216
4.5	1,274	1.056	.924	.804	.672	.564	.468	.384	.312	.240
5.	1,146	1.188	1.032	.888	.756	.636	.528	.420	.348	.264
5.5	1,042	1.296	1.128	.984	.840	.708	.576	.468	.384	.288
6.	955.4	1.404	1.224	1.056	.912	.768	.624	.504	.408	.312
6.5	882	1.536	1.344	1.164	.984	.828	.684	.552	.444	.336
7.	819	1.644	1.440	1.248	1.056	.888	.732	.588	.468	.360
7.5	764.5	1.752	1.524	1.332	1.128	.948	.780	.636	.504	.384
8.	716.8	1.896	1.644	1.428	1.200	1.020	.840	.672	.540	.408
8.5	674.6	1.992	1.740	1.512	1.272	1.080	.888	.720	.576	.432
9.	637.3	2.100	1.836	1.596	1.344	1.140	.936	.756	.600	.456
9.5	603.8	2.244	1.956	1.692	1.428	1.212	.996	.804	.648	.504
10.	573.7	2.352	2.052	1.776	1.500	1.272	1.044	.852	.684	.540
11.	521.7	2.592	2.256	1.956	1.668	1.404	1.152	.936	.756	.568
12.	478.3	2.832	2.472	2.148	1.812	1.536	1.260	1.020	.828	.636
13.	441.7	3.048	2.664	2.304	1.956	1.656	1.356	1.104	.900	.684
14.	410.3	3.300	2.868	2.484	2.100	1.776	1.464	1.188	.960	.732
15.	383.1	3.540	3.084	2.676	2.256	1.908	1.572	1.272	1.020	.780
16.	359.3	3.756	3.276	2.832	2.400	2.040	1.668	1.356	1.092	.840
17.	338.3	3.996	3.480	3.024	2.556	2.160	1.776	1.440	1.152	.888
18.	319.6	4.212	3.672	3.180	2.700	2.280	1.872	1.524	1.224	.936
19.	302.9	4.452	3.888	3.360	2.856	2.412	1.980	1.608	1.296	.984
20.	287.9	4.704	4.092	3.552	3.000	2.544	2.088	1.692	1.368	1.044

Note—This table is slightly modified in form from that prepared by Mr. John C. Trautwine for his "Civil Engineers' Pocket Book."

Engineering Data

Table for the Elevation of the Outer Rail on Curves

Degree of Curvature	Rate of Speed in Miles per Hour: 15	20	25	30	35	40	45	50	60
	Elevation of Outer Rail in Inches								
30′	1/16	1/8	3/16	1/4	3/8	1/2	11/16	13/16	1 1/8
1° 00′	1/8	1/4	7/16	5/8	11/16	1 1/16	1 5/16	1 5/8	2 3/8
1° 30′	3/16	3/8	5/8	7/8	1 3/16	1 9/16	2	2 1/2	3 1/2
2° 00′	5/16	1/2	13/16	1 1/8	1 5/8	2 1/8	2 11/16	3 1/4	4 5/8
2° 30′	3/8	11/16	1	1 1/2	2	2 11/16	3 5/16	4 1/16	5 15/16
3° 00′	7/16	13/16	1 1/4	1 3/4	2 7/16	3 1/8	4	4 15/16	7
3° 30′	1/2	15/16	1 7/16	2 1/16	2 13/16	3 11/16	4 5/8	5 3/4	8 5/16
4° 00′	9/16	1 1/16	1 5/8	2 3/8	3 1/4	4 3/16	5 5/16	6 1/4	9 7/16
4° 30′	11/16	1 3/16	1 7/8	2 5/8	3 5/8	4 11/16	6	7 3/8	10 9/16
5° 00′	3/4	1 5/16	2 1/16	3	4	5 1/4	6 5/8	8 3/16	11 7/8
6° 00′	7/8	1 9/16	2 7/16	3 1/2	4 13/16	6 5/16	8	9 7/8	14 1/16
7° 00′	1	1 7/8	2 7/8	4 1/8	5 5/8	7 3/8	9 1/4	11 1/2	16 1/2
8° 00′	1 3/16	2 1/8	3 5/16	4 11/16	6 7/16	8 3/8	10 5/8	13 1/8	18 7/8
9° 00′	1 5/16	2 3/8	3 11/16	5 5/16	7 1/4	9 7/16	11 15/16	14 3/4	21 5/16
10° 00′	1 1/2	2 5/8	4 1/8	5 7/8	8	10 1/2	13 1/4	16 3/8	23 1/2
12° 00′	1 3/4	3 1/8	4 15/16	7 1/16					
15° 00′	2 1/4	3 15/16	6 1/8	9 1/16					
18° 00′	2 11/16	4 11/16	7 3/8	10 9/16					
20° 00′	2 15/16	5 1/4	8 3/16	11 3/4					
25° 00′	3 13/16	6 13/16	10 5/8	15 5/16					
30° 00′	4 3/8	7 13/16	12 3/16	17 1/2					



Typical Track Sections

Engineering Data

Power to Propel Cars

Data Based on Paper Read by A. H. Armstrong at Annual Meeting of A. I. E. E., June 30, 1903

Stops per Mile	Schedule Speed	W. H. per Ton M.	Schedule Speed	W. H. per Ton M.	Schedule Speed	W. H. per Ton M.	Schedule Speed	W. H. per Ton M.
.0	30.	40	45	63	60	97	75	140
.2	27.5	44	40	72	50	110	55	155
.4	25.	48	35	80	42	122	45	170
.6	23.5	51	32	87	36	133	38	183
.8	22.5	54	29	94	32	143	33	196
1.0	21.5	57	27	100	29	153	30	208
1.2	20.5	61	25	106	27	162	27.5	217
1.4	19.5	64	23	111	25	170		
1.6	18.5	67	22	116	23	177		
1.8	18.8	69	21	121	22	184		
2.0	17.	71	20	126	21	190		
2.2	16.5	73	19	130	20	196		
2.4	16.	76	18	135				
2.6	15.5	78	17	140				
2.8	15.0	80	16	144				
3.0	14.5	82						

Physical Properties of Metals

Metals	Ultimate Tensile Strength Pounds per Square Inch	Melting Point in Cent. Degrees	Specific Heat	Coefficient of Linear Expansion Below 100 Degrees Cent.	Ohms Res. per Mil Foot, 20 Degrees Cent.	Temp. Coefficient K. Cent. Degrees
Antimony	. . .	440	0.0508	0.00001129	230.2	0.00389
Aluminum, annealed	15,000	625	.2185	.00002310	18.21	.00390
Bismuth	6,400	266	.0298	.00001755	845.20	.00354
Brass, cast	18,000	1020	.0939	.00001720	45.00	. . .
Copper, annealed	30,000	1054 to	.0951	.00001596	10.35	.00388
Copper, hard drawn	60,000	1200	.0951	. . . . .	10.7	.00388
German silver wire	87,000	1093	. . .	. . . . .	126.6	.000443
Gold, annealed	. . .	1046	.0324	.00001415	13.28	.00365
Iron, cast	16,500	1220	.1298	.00001001	380.	.00453
Iron, wrought	52,000	1620	.1138	.000011660	63.21	.0054
Lead	3,300	325	.0314	.00002828	126.10	.00387
Manganese steel	. . .	1260	. . .	. . . . .	245.	.00122
Mercury	. . .	—39.4	.0333	.00006	577.6	.0007485
Nickel	. . .	1620	.1150	.00001251	74.73	.0041
Platinum	. . .	1800	.0324	.00000863	56.69	.0039
Phosphor bronze	64,700	. . .	. . .	. . . . .	39.6	. . .
Silicon bronze	75,000	. . .	. . .	. . . . .	12.9	. . .
Silver	. . .	950	.0570	.00001943	10.48	.00377
Steel, high carbon	100,000	1410	.1175	.00001240	118.	.0050
Solder, tin 1, lead 1	7,500	187	. . .	. . . . .	111.	. . .
Tin	4,500	230	.0562	.00002094	84.57	.00365
Zinc	7,500	416	.0956	.00002532	36.60	.00365

Engineering Data

Weight and Specific Gravity of Various Materials

Name	Weight in Pounds		Specific Gravity
	Per Cubic Foot	Per Cubic Inch	
Water, pure, 60°F.	62.3	.036	1.00
Water, sea	64.3	.037	1.03
METALS			
Iron, cast	450	.260	7.22
Iron, wrought	480	.278	7.70
Iron, steel	490	.283	7.85
Aluminum	166.5	.096	2.67
Brass	524	.302	8.40
Bronze	552	.320	8.85
Copper	554	.32	8.89
Gold	1208	.697	19.36
Lead	710	.410	11.40
Platinum	1344	.775	21.53
Silver	655	.377	10.50
Tin	458	.265	7.35
Zinc	437	.253	7.00
MINERALS			
Asphalt	87	.050	1.39
Brick, soft	100	.058	1.60
Brick, hard	125	.071	2.00
Brick, pressed	135	.077	2.16
Brickwork, ordinary	112	.064	1.80
Brickwork, fine	120	.068	2.10
Clay	119	.068	1.92
Coal, anthracite	96	.056	1.57
Coal, bituminous	84	.048	1.35
Coke	63	.036	1.01
Concrete cement	130	.075	2.20
Earth, from	90	.052	1.63
Earth, to	135	.068	1.92
Felspar	162	.094	2.60
Flint	164	.095	2.63

Name	Weight in Pounds		Specific Gravity
	Per Cubic Foot	Per Cubic Inch	
Glass, crown	156	.090	2.52
Glass, plate	172	.099	2.76
Glass, flint	192	.111	3.07
Granite	164	.095	2.63
Gypsum	143	.082	2.28
Lime, quick	53	.030	0.84
Limestone	168	.100	2.80
Marl	119	.069	1.90
Masonry, from	120	.068	1.90
Masonry, to	144	.083	2.30
Mortar, average	109	.063	1.75
Mud	102	.059	1.63
Petroleum	55	.032	0.88
Plumbago	140	.081	2.27
Sand, average	100	.058	1.61
Sandstone	144	.083	2.30
Shale	162	.094	2.60
Slate	175	.101	2.80
Trap	170	.098	2.72
WOODS			
Apple	47	.028	0.76
Ash	45	.026	0.72
Cedar	39	.022	0.62
Cherry	42	.024	0.67
Chestnut	35	.020	0.56
Hemlock	24	.015	0.38
Maple	42	.026	0.68
Oak, white	48	.030	0.77
Oak, red	45	.026	0.74
Pine, white	28	.017	0.45
Pine, yellow	38	.020	0.61
Walnut	36	.020	0.58

Engineering Data

Linear

1 meter = 39.3704 inches = 3.281 feet = 1.094 yards.
Centimeter (1-100 meter) = 0.3937 inch.
1 millimeter (mm.) = .03937 inch = 39.37 mils.
1 inch = 25.3997 millimeters = .083 foot = 2.54 centimeters.
1 kilometer = 1,000 meters, or 3,281 feet = .6213 mile.
For the purpose of memory, a meter may be considered as 3 feet 3⅓ inches.

Surface Measures

Centare (1 square meter) = 1,550 square inches = 10.764 square feet.
Are (100 square meters) = 119.6 square yards.
1 square centimeter = 0.155 square inch = 197,300 circular mils.
1 square millimeter = .00155 square inch = 1973 circular mils.
1 square inch = 6.451 square centimeters = .0069 square foot.
1 square foot = 929.03 square centimeters = .0929 square meter.

Weights

Milligram (1-1,000 gram) = 0.0154 grain.
Centigram (1-100 gram) = 0.1543 grain.
Decigram (1-10 gram) = 1.5432 grains.
Gram = 15.432 grains.
Decagram (10 grams) = 0.3527 ounce.
Hectogram (100 grams) = 3.5274 ounces.
Kilogram (1,000 grams) = 2.2046 pounds.
Myriagram (10,000 grams) = 22.046 pounds.
Quintal (100,000 grams) = 220.46 pounds.
Millier or tonne—ton (1,000,000 grams) = 2,204.6 pounds.

Volumes

Milliliter (1-1,000 liter) = 0.061 cubic inch.
Centiliter (1-100 liter) = 0.6102 cubic inch.
Deciliter (1-10 liter) = 6.1023 cubic inches.
Liter = 1,000 cu. cm. = 61.023 cubic inches.
Hectoliter (100 liters) = 2.838 bushels.
Kiloliter (1,000 liters) = 1,308 cubic yards.

Liquid Measures

Milliliter (1-1,000 liter) = 0.0338 fluid ounce.
Centiliter (1-100 liter) = 0.338 fluid ounce.
Deciliter (1-10 liter) = 0.845 gill.
Liter = 0.908 quart = 0.2642 gallon.
Decaliter (10 liters) = 2.6418 gallons.
Hectoliter (100 liters) = 26.418 gallons.
Kiloliter (1,000 liters) = 264.18 gallons.

Engineering Data

The C. G. S. electrical units are derived from the following fundamental units:

The centimeter, the union of length.
The gramme, the unit of mass.
The second, the unit of time.

The centimeter equals .3937 of an inch, or one thousand-millionth part of a quadrant of the earth.

The gramme is equal to 15.432 grains, the mass of a cubic centimeter of water at 4° C.

The second is the time of one swing of the pendulum, making 86,464.09 swings per day, or the 1-86400 part of a mean solar day.

Mensuration

Circumference of circle whose diameter is $1 = \pi = 3.14159265$.
Circumference of any circle $=$ diameter $\times\ \pi$.
Area of any circle $= (\text{radius})^2 \times \pi$, or $(\text{diameter})^2 \times 0.7854$.

Surface of sphere $= (\text{diameter})^2 \times \pi$, or $=$ circumference $\times$ diameter.
Volume of sphere $= (\text{diameter})^3 \times 0.5236$, or $=$ surface $\times \frac{1}{6}$ diameter.

Area of an ellipse $=$ long diameter $\times$ short diameter $\times$ 0.7854.
$\pi^2 = 9.8696$; $\pi^{\frac{1}{2}} = 1.772454$; $\pi/4 = 0.7854$.
$1/\pi = 0.31831$; $\log \pi = 0.4971499$.
Basis of natural log; $\varepsilon = 2.7183$; $\log \varepsilon = 0.43429$.

Modulus of natural logarithm $M = \frac{1}{\log \varepsilon} = 2.3026$.

1 lb. per sq. inch $=$
- 144 lb. per sq. foot.
- 51.7116 mm. of mercury.
- 2.30665 feet of water.
- 0.072 ton (short) per sq. foot.
- 0.0680415 atmosphere.

One mile = 320 rods = 1760 yards = 5280 feet = 63,360 inches.
One fathom = 6 feet; 1 knot = 6080 feet = 1.15 miles.
1 cubic foot = 1728 cubic inches.
1 liquid gallon = 231 cubic inches = 0.134 cubic foot
1 pound avoirdupois = 7000 grains = 453.6 grammes.
The angle of which the arc is equal to the radius, a Radian = 57.2958°.

Physical Data

The equivalent of one B. t. u. of heat = 778 foot-pounds.
The equivalent of one calorie of heat = 426 kg-m., = 3.968 B. t. u.
One cubic foot of water weighs 62.355 pounds at 62° F.
One cubic foot of air weighs 0.0807 pound at 32° F. and one atmosphere.
One cubic foot of hydrogen weighs 0.00557 pound.
One foot-pound $= 1.3562 \times 10^7$ ergs.
One horse-power hour $= 33{,}000 \times 60$ foot-pounds.

Engineering Data

One horse-power = 33,000 foot-pounds per min. = 550 foot-pounds per second = 746 watts = 2545 B. t. u. per hour.

Acceleration of gravity (g) = 32.2 feet per second.
= 980 c. m. per second.

One atmosphere = 14.7 pounds per square inch.
= 2116 pounds per square foot
= 760 mm. of mercury.

Velocity of sound at 0° cent. in dry air = 332.4 meters per second
= 1091 feet per second.

Velocity of light in vacuum = 299,853 km. per second.
= 186,325 miles per second.

Specific heat of air at constant pressure = 0.237.

A column of water 2.3 feet high corresponds to a pressure of 1 pound per square inch.

Coefficient of expansion of gases = $\frac{1}{273}$ = 0.00367.

Latent heat of water = 79.24 cal.

Latent heat of steam = 535.9 cal.

Centigrade Degrees. To convert into the corresponding one in Fahrenheit degrees multiply by $^9/_5$ and add 32. To convert it into the one in Réaumur degrees multiply by $^4/_5$. To convert it into the one on the Absolute scale, add 273.

Fahrenheit Degrees. To convert into Centigrade degrees, subtract 32 and then multiply by $^5/_9$, being careful about the signs when the reading is below the melting point of ice To convert it into Réaumur degrees, subtract 32 and multiply by $^4/_9$ To convert it into the Absolute scale, subtract 32, multiply by 5, add 2297, and divide by 9

Decimals of an Inch and Millimeters for each 1-64 Inch

$\frac{1}{32}$ In.	$\frac{1}{64}$ In.	Decimal Inch	mm.	Fraction	$\frac{1}{32}$ In.	$\frac{1}{64}$ In.	Decimal Inch	mm.	Fraction	$\frac{1}{32}$ In.	$\frac{1}{64}$ In.	Decimal Inch	mm.	Fraction	$\frac{1}{32}$ In.	$\frac{1}{64}$ In.	Decimal Inch	mm.	Fraction
	1	.015625	.3968			17	.265625	6.7467			33	.515625	13.0966			49	.765625	19.4465	
1	2	.03125	.7937		9	18	.28125	7.1436		17	34	.53125	13.4934		25	50	.78125	19.8433	
	3	.046875	1.1906			19	.296875	7.5404			35	.546875	13.8903			51	.796875	20.2402	
2	4	.0625	1.5874	$\frac{1}{16}$	10	20	.3125	7.9373	$\frac{5}{16}$	18	36	.5625	14.2872	$\frac{9}{16}$	26	52	.8125	20.6371	$\frac{13}{16}$
	5	.078125	1.9843			21	.328125	8.3342			37	.578125	14.6841			53	.828125	21.0339	
3	6	.09375	2.3812		11	22	.34375	8.7310		19	38	.59375	15.0809		27	54	.84375	21.4308	
	7	.109375	2.7780			23	.359375	9.1279			39	.609375	15.4778			55	.859375	21.8277	
4	8	.125	3.1749	$\frac{1}{8}$	12	24	.375	9.5248	$\frac{3}{8}$	20	40	.625	15.8747	$\frac{5}{8}$	28	56	.875	22.2245	$\frac{7}{8}$
	9	.140625	3.5718			25	.390625	9.9216			41	.640625	16.2715			57	.890625	22.6214	
5	10	.15625	3.9686		13	26	.40625	10.3185		21	42	.65625	16.6684		29	58	.90625	23.0183	
	11	.171875	4.3655			27	.421875	10.7154			43	.671875	17.0653			59	.921875	23.4151	
6	12	.1875	4.7624	$\frac{3}{16}$	14	28	.4375	11.1122	$\frac{7}{16}$	22	44	.6875	17.4621	$\frac{11}{16}$	30	60	.9375	23.8120	$\frac{15}{16}$
	13	.203125	5.1592			29	.453125	11.5091			45	.703125	17 8590			61	.953125	24.2089	
7	14	.21875	5.5561		15	30	.46875	11.9060		23	46	.71875	18.2559		31	62	.96875	24.6057	
	15	.234375	5.9530			31	.484375	12.3029			47	.734375	18.6527			63	.984375	25.0026	
8	16	.2500	6.3498	$\frac{1}{4}$	16	32	.500	12.6997	$\frac{1}{2}$	24	48	.75	19.0496	$\frac{3}{4}$	32	64	1.0000	25.3995	1

Engineering Data

Areas and Circumferences of Circles

Diameter	Circumference	Area
1/64	.049087	.00019
1/32	.098175	.00077
3/64	.147262	.00173
1/16	.196350	.00307
3/32	.294524	.00690
1/8	.392699	.01227
5/32	.490874	.01917
3/16	.589049	.02761
7/32	.687223	.03758
1/4	.785398	.04909
9/32	.883573	.06213
5/16	.981748	.07670
11/32	1.07992	.09281
3/8	1.17810	.11045
13/32	1.27627	.12962
7/16	1.37445	.15033
15/32	1.47262	.17257
1/2	1.57080	.19635
17/32	1.66897	.22166
9/16	1.76715	.24850
19/32	1.86532	.27688
5/8	1.96350	.30680
21/32	2.06167	.33824
11/16	2.15984	.37122
23/32	2.25802	.40574
3/4	2.35619	.44179
25/32	2.45437	.47937
13/16	2.55254	.51849
27/32	2.65072	.55914
7/8	2.74889	.60132
29/32	2.84707	.64504
15/16	2.94524	.69029
31/32	3.04342	.73708
1.	3.14159	.78540
1/16	3.33794	.88664
1/8	3.53429	.99402
3/16	3.73064	1.1075
1/4	3.92699	1.2272
5/16	4.12334	1.3530
3/8	4.31969	1.4849
7/16	4.51604	1.6230
1/2	4.71239	1.7671
9/16	4.90874	1.9175
5/8	5.10509	2.0739
11/16	5.30144	2.2365
3/4	5.49779	2.4053
13/16	5.69414	2.5802
7/8	5.89049	2.7612
15/16	6.08684	2.9483

Diameter	Circumference	Area
2.	6.28319	3.1416
1/16	6.47953	3.3410
1/8	6.67588	3.5466
3/16	6.87223	3.7583
1/4	7.06858	3.9761
5/16	7.26493	4.2000
3/8	7.46128	4.4301
7/16	7.65763	4.6664
1/2	7.85398	4.9087
9/16	8.05033	5.1572
5/8	8.24668	5.4119
11/16	8.44303	5.6727
3/4	8.63938	5.9396
13/16	8.83573	6.2126
7/8	9.03208	6.4918
15/16	9.22843	6.7771
3.	9.42478	7.0686
1/16	9.62113	7.3662
1/8	9.81748	7.6699
3/16	10.0138	7.9798
1/4	10.2102	8.2958
5/16	10.4065	8.6179
3/8	10.6029	8.9462
7/16	10.7992	9.2806
1/2	10.9956	9.6211
9/16	11.1919	9.9678
5/8	11.3883	10.321
11/16	11.5846	10.680
3/4	11.7810	11.045
13/16	11.9773	11.416
7/8	12.1737	11.793
15/16	12.3700	12.177
4.	12.5664	12.566
1/16	12.7627	12.962
1/8	12.9591	13.364
3/16	13.1554	13.772
1/4	13.3518	14.186
5/16	13.5481	14.607
3/8	13.7445	15.033
7/16	13.9408	15.466
1/2	14.1372	15.904
9/16	14.3335	16.349
5/8	14.5299	16.800
11/16	14.7262	17.257
3/4	14.9226	17.721
13/16	15.1189	18.190
7/8	15.3153	18.665
15/16	15.5116	19.147

Diameter	Circumference	Area
5.	15.7080	19.635
1/16	15.9043	20.129
1/8	16.1007	20.629
3/16	16.2970	21.135
1/4	16.4934	21.648
5/16	16.6897	22.166
3/8	16.8861	22.691
7/16	17.0824	23.221
1/2	17.2788	23.758
9/16	17.4751	24.301
5/8	17.6715	24.850
11/16	17.8678	25.406
3/4	18.0642	25.967
13/16	18.2605	26.535
7/8	18.4569	27.109
15/16	18.6532	27.688
6.	18.8496	28.274
1/8	19.2423	29.465
1/4	19.6350	30.680
3/8	20.0277	31.919
1/2	20.4204	33.183
5/8	20.8131	34.472
3/4	21.2058	35.785
7/8	21.5984	37.122
7.	21.9911	38.485
1/8	22.3838	39.871
1/4	22.7765	41.282
3/8	23.1692	42.718
1/2	23.5619	44.179
5/8	23.9546	45.664
3/4	24.3473	47.173
7/8	24.7400	48.707
8.	25.1327	50.265
1/8	25.5254	51.849
1/4	25.9181	53.456
3/8	26.3108	55.088
1/2	26.7035	56.745
5/8	27.0962	58.426
3/4	27.4889	60.132
7/8	27.8816	61.862
9.	28.2743	63.617
1/8	28.6670	65.397
1/4	29.0597	67.201
3/8	29.4524	69.029
1/2	29.8451	70.882
5/8	30.2378	72.760
3/4	30.6305	74.662

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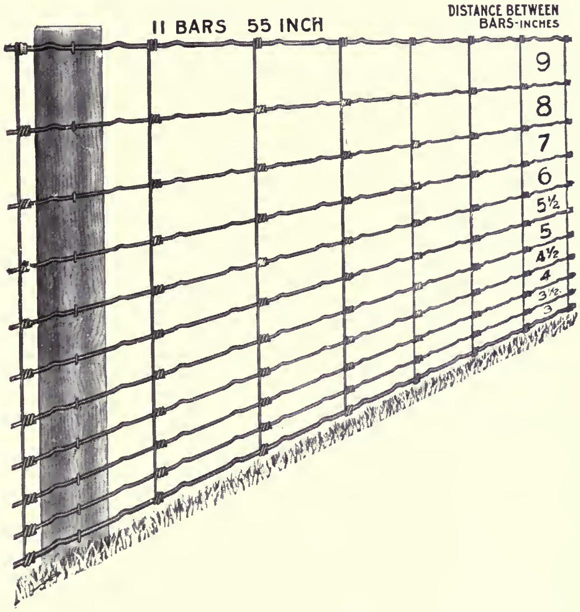
American Steel & Wire Company



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