

ELECTRIFICATION OF C. M. & ST. PAUL RAILWAY  
FROM HARLOWTOWN, MONT.  
TO AVERY, IDAHO

BY

M. CURTIS

ARMOUR INSTITUTE OF TECHNOLOGY

1916

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Electrification work of the  
Chicago, Milwaukee & St.

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Electrification Work of the Chicago,

Milwaukee & St. Paul Railway

From Harlowtown, Montana to Avery, Idaho

A THESIS

Presented By

Marston Curtis

To The

FACULTY AND PRESIDENT

Of

ARMOUR INSTITUTE OF TECHNOLOGY

For The Degree Of

ELECTRICAL ENGINEER

Approved

*E. H. Freeman*

*Prof. of Elect. Engineering*

*L. C. Momin,  
Dean of Elect. Studies.*

*J. M. Raymond*



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ELECTRIFICATION OF THE CHICAGO, MILWAUKEE & ST.  
PAUL RAILWAY FROM HARLOWTOWN, MONTANA TO  
AVERY, IDAHO.

In the spring of 1914 the Chicago, Milwaukee & St. Paul Railway Company established its electrification department and by early fall of the same year had started actual construction work between Three Forks and Deer Lodge, Montana. The territory between Harlowtown and Avery, covering four steam engine divisions, a distance of approximately 440 miles of main line, was divided into three sections, namely Three Forks to Deer Lodge, Harlowtown to Three Forks and Deer Lodge to Avery. The first two sections are about 110 miles long, while the third is 220 miles. The first section was completed in the fall of 1915, the second in the early part of 1916, and the third will be completed before the end of the present year (1916).

The work consists of constructing a trolley overhead contact system, including feeder, signal and power limiting wires, bonding of the rails, construction of a high voltage transmission line, and the building of substations.



The trolley overhead system includes two 4/0 copper, grooved contact wires, suspended by a steel catenary and insulated for 3000 volts D. C. The contact wires are hung from brackets or spans attached to the poles. On these poles the feeder wires are supported by four pin cross arms on which are also the two signal wires which carry 4400 volts A. C. At the top of, and fastened to the pole by a clamp, is the 4/0 stranded copper cable used as a supplementary negative. The power-limiting wires, which are not strung at the present time, are to be attached to a two pin cross arm on the trolley pole and will carry 1500 volts D. C.

The high voltage transmission line consists of a 100,000 volt, 3 phase, 60 cycle line of 2/0 hemp core, copper strand. On the top cross arms of the same pole is carried a 3/8 inch Siemens-Martin steel strand, used as a ground for the transmission line.

The general lay-out of the trolley and transmission lines as located on the company's right-of-way is shown on drawings E. D. 17 and 168. The former drawing shows construction around a curve to the left with the transmission line on the outside of the curve, and in some instances, the line is located on the inside of the curve as shown by the dotted lines. A general idea of the transmis-



sion line construction may be had from the drawing and will be explained in detail a little later. The table showing the length of spans for various degrees of curvature was made so as not to make an angle greater than 10 degrees on any one pole of the ordinary curve construction type, while for a tangent the standard span is 300 feet with a maximum angle of 3 degrees. Drawing 168 shows the relative positions of the transmission wires on tangent work and also the location of the wires on the trolley poles.

A general idea of the system used may be had from drawing E. D. 125 A, which shows the substations and transmission and trolley lines from Two Dot to Morel. In the territory between Harlowtown and Deer Lodge there are seven substations, with an average distance of thirty and a half miles between them. At five of these substations, namely Two Dot, Josephine, Piedmont, Janney and Morel there are power taps from the 100,000 volt lines of the Montana Power Company. The substations are all connected together by the Railway's transmission line, and any one of them may be isolated from the rest of the system by the opening of switches as shown on the drawing. The size and main equipment of the substations are as follows:



Two Dot, Summit, Josephine, Eustis and Morel each have 2-2500 KVA, 100,000-2300 volt, 3 phase transformers, and 2-2000 KW, 3000 volt motor generator sets; Piedmont and Janney each have 3-1900 KVA, 100,000-2300 volt, 3 phase transformers and 3-1500 KW, 3000 volt D.C. motor generator sets. On the West end the substations are located at Cold Creek, Ravenna, Primrose, Tarkio, Drexel, East Portal, Montana and Avery, Idaho. The first five substations each have a 2-2500 KVA, 100,000-2300 volt, 3 phase transformer and 2-2000 KW, 3000 volt D.C. motor generator sets; East Portal has 3-2500 KVA transformers and 3-2000 KW motor generator sets, while Avery has 3-1900 KVA transformers and 3-1500 KW motor generator sets.

The trolley and feeder systems are sectionalized at substations, yards and long tunnels as may be seen roughly from the drawing. Likewise the system of installation of reactance bonds.

The scheme for the lay-out of the trolley poles in the field was to so locate them that the standard bracket pole could be used as often as possible. This meant that the feeder had to be on the outside of all curves and where curves were encountered that were too short in length or where local conditions required it, a span construction was resorted to, and in a few instances stiff braces were used on the poles where the latter had to be

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set on the inside of curves. Wherever two or more tracks had to be wired span construction was used.

The standard trolley bracket construction is shown on E. D. 3. The mast arm is 2-1/4" by 2-1/4" by 3/16" T iron, fastened to the pole by a shoe casting and 5/8" round bracket rods. These T irons vary in length from 12'6" to 13'6", and a few 14'6" mast arms are used. The 12'6" arms are used on tangent and curve work up to 6 degrees inclusive, while the 13'6" arms are used on curves over 6 degrees. The longer arms were used where there was an excessive amount of super-elevation, or where the poles had to be raked more than the standard amount which is 12" at a point 24 feet above top of rail.

The messenger wire is of 1/2", high strength S.M. steel strand and is supported on the mast arm by a porcelain insulator and J bolt. The feeder and power-limiting cross arms on the East end are 3-3/4" by 4-3/4" by 5'6" and by 3'0" respectively. On the West end they are 5'7" and 3'2" to give additional clearance between pole pin wires as required by the state of Idaho. These arms are of clear fir and the larger ones are attached to the pole by 3/4" inch through bolts and



1-1/4" by 1/4" by 28" galvanized iron braces, while the smaller arms are attached by 5/8 inch through bolts and 20" braces. Trolley poles are set 5'6" in earth for bracket tangent construction, curves and on span construction: 4'0" in rock for bracket curves and all span construction, and 5' in rock for bracket tangent construction.

The trolley pole spacing on the East end and the number<sup>of</sup> pull-offs per wire are as follows:

Tangent track	150' spacing	0 pull-offs
1 degree curve	150' "	1 " "
2 " "	150' "	2 " "
3 " "	135' "	2 " "
4 " "	120' "	2 " "
5-6 " "	105' "	2 " "
7-9 " "	90' "	2 " "
10-12 " "	90' "	3 " "
13-15 " "	75' "	3 " "
16-18 " "	60' "	3 " "

On the West end the pole spacing and pull-offs are as follows:

Tangent track	150' spacing	0 pull-offs
1° 30' curve	150' "	1 " "
2° 30' "	135' "	1 " "
3 degree "	120' "	1 " "
4 " "	105' "	1 " "
5-6 " "	90' "	1 " "
7-9 " "	90' "	2 " "



10-12 degree curve	90'	spacing	3	pull-offs
13-15       "       "	75'	"	3	"       "
16-18       "       "	60'	"	3	"       "

The reason for the change in the pole spacing and pull-offs was made because it was found that by changing the pole spacing the back-bone on a very large percentage of the curves could be omitted, for where there is more than one pull-off per wire there has to be a 3/8" back-bone, which runs up the expense of construction because of the additional insulation needed and the anchorage at the ends of the curves besides the material used.

Poles in curves of 3 degrees and over on the East end and 4 degrees and over on the West end are provided with double arms for the feeder because of the otherwise high stresses which would come on the pins. The two arms are tied together by 5/8" spacing bolts. A 3/8" S.M. steel strand guy on bracket construction with one feeder ( 500,000 or 750,000 C.M. ) is used on all curves up to and including 4 degrees, while 1/2" guys are used on the curves over 4 degrees. Where there are two feeders, 3/8" guys are used on curves up to and including 2 degrees, and 1/2" guys on curves above 2 degrees. In span construction, single track, one feeder, 3/8" guys are used on both sides for curves up to and including 4 degrees and 3/8" on



inside and  $1/2$ " on outside of all curves above 4 degrees. On single track with two feeders  $3/8$ " guys are used on both sides for curves up to and including 2 degrees and  $3/8$ " inside and  $1/2$ " outside for curves above 2 degrees. On double track  $3/8$ " inside and  $1/2$ " outside guys are used on all curve work. On three track  $1/2$ " strand is used for guy "E" ( see ED 41) and  $3/8$ " for guy "F" on outside of curves up to and including 4 degrees. For curves over 4 degrees  $1/2$ " strand is used for both "E" and "F" on outside of curve. On four tracks  $1/2$ " guys are used for both "E" and "F" on outside of all curves and with five tracks and over  $5/8$ " strand is used for both "E" and "F" on outside of all curves. The guys on the inside of curves for three tracks and over are the same as those for tangent track work as shown in the table on ED 41.

The catenary hangers are spaced every 15' on single trolley and on the main line where double trolley is used the hangers are staggered so that there is one every 7'6" of line. This arrangement insures permanent contact of at least one wire with the pantograph at all times and cuts down arcing to practically zero. The hanger lengths are all based on a 29" deflection at the point of suspension of the messenger. The various lengths used for the



various pole spacings are shown on drawing ED 107A. Single contact wire is used on passing tracks, industries and in yards, while on the main line double contact wire is used. Single contact wire is used at these points because it was found that the wires were helped out in their current carrying capacity by the adjoining and main line trolley.

Where there is only one pull-off per wire on a span it is attached to the trolley wire at the pole. The pull-offs used are flexible so as to eliminate hard spots in the contact wire. At first there were struts used in connection with the pull-offs but it was later found that these were unnecessary and are being eliminated. On spirals running into curves there are usually one or two poles with steady braces attached to the mast arm for lining the trolley, as well as on all curves of one degree and less. These were only used at points where there was a very slight angle at the pole or where the contact wire had to be pushed away from the pole at such points as on push curves (where the bracket poles are set on the inside of curves).

In tunnels the messenger deflection is 13" and the spans are 45 feet in length for trolley and 22'6" for feeder. The hangers used are of the collapsible type because of the limited head room for movement of the trolley wires. The messenger and feeder are suspended from the channel irons hung in the roofs of tunnels and are insulated by



two single disk insulators. Drawing ED 118 shows the general scheme for tunnel work and it will be noted that the power-limiting and signal wires are run through the tunnel in two lead-sheathed cables supported at the side of the tunnel from the supplementary negative which is run through the eyes of one inch expansion bolts. The height of the trolley wires in the tunnels is only 19'2-1/2" while on the open track it is 24'2", which means that the trolley wire has to be graded to the tunnel at the rate of one foot in one hundred. In all tunnels which are 1200 feet and more in length air brakes are inserted in the trolley and messenger at each end of the tunnel and <sup>opposite</sup> these air brakes are located feeder cut-out switches so that in case of trouble inside of tunnel all wires can be killed by simply opening the two switches.

The trolley span construction is built according to the lay-out shown on drawing ED 41. The guys and other working tables are all figured for the condition of 1/2" ice on wires and 3-1/2 pounds per square foot wind pressure, also a liberal factor of safety has been allowed.

For single and double track work no steady span is used, the trolleys being suspended directly from the main cross span. For three tracks and over a steady is used of 3/8" S.M. strand because



of the increased length in the drops. On single and double track work the messenger is suspended from the cross span by plain span messenger hangers, while on the heavier track work span messenger hangers with eyes or ring tops are used. On the drawing only single insulation is shown for simplicity, but instructions were issued that all insulation should consist of two porcelain strain insulators in series, except those used in the guys which are single units. In other words the insulation between 3000 volts and ground or pole is double while single insulation is used between pole and anchor. Where the cross span cable "D" is 5/8" the insulation at points "J" is omitted and double insulation is cut into each drop because the hole in the insulator is not sufficient to admit a strand of this size.

The anchors used on all trolley work consists of a 3/4" or 1" galvanized iron rod, the size depending on the size of guy strand, and a 1' by 1' by 4' timber slug or deadman buried in 5' of earth. Where rock is encountered 1-1/2" galvanized iron eye bolts are used.

The trolley and messenger is anchored every 4000' so that the slack due to a break in the trolley or messenger would not effect sections greater than the length of the anchorages. The detail

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry should be supported by a valid receipt or invoice. The second part outlines the procedures for handling discrepancies and errors, stating that any such issues should be reported immediately to the relevant department. The third part details the process for auditing the accounts, including the selection of samples and the use of statistical methods to ensure the reliability of the data. The final part concludes with a statement of the overall findings and a recommendation for further improvements in the accounting system.

of construction of these anchorages is shown on drawing ED 50. Two spans are required for a trolley and messenger dead end and an additional pole has to be used for the anchorage of the strand which runs diagonally across the track from pole #1, for instance, to pole #3. This strand crosses the messenger at pole #2 which is the middle pole, and is attached to the messenger insulator on this pole by four 5/8" Crosby Clips. This anchorage has inserted in it on either side of the messenger double insulation as shown. Two lengths of 3/8" steel strand are run through these same 5/8" Crosby Clips and are attached to anchor ears fastened to each trolley, and four turn-buckles are inserted in this strand to take up any slack. The poles to which this anchorage strand is attached are head guyed and side guyed to keep the heavy stress off of these poles.

Every 1000' taps are taken from the feeder, or feeders, to the trolleys so as to reduce the drop on the trolley to a minimum. These taps, drawing ED 138, are 4/0 bare copper strand and one end is served around the feeder and clipped to the same by one Crosby, and is then run through a special bracket attached to the mast arm from where it goes to the messenger, and from there drops down to the



feed tap ears on the trolley wire. These brackets on the T iron are of special and original design and are made of 1" Channel iron with a wire thread for the 3000 volt porcelain insulator. Where feeder taps are used on span work a two pin cross arm is attached to the pole and used in place of the special bracket.

Wherever it is necessary, because of ground conditions, to transfer the feeder and signal wires from one side of the track to the other it is necessary to use a special crossing scheme, drawing ED 126. The position of the signal and power-limiting wires as shown on drawing ED 3 have been interchanged from their original positions which are still shown on ED 126. This change was made because the signal wires had been strung and at present it is not known when the power-limiting wires are to be built. The two crossing poles are 45' in length, while the standard trolley pole is only 40', and at the top of the pole are double buck arms. The scheme for crossing the wires over the track is as follows: Wire #1, which is a power-limiting conductor, is dead ended on the lower side of the buck arm, rises at point "A" to the height of the upper cross arm insulator and from there over the top of the two insulators, dropping down at point "B" to the level of the dead end eye bolt in the

The first part of the document is a preface, written by the author, in which he explains the purpose and scope of the work. He states that the book is intended to provide a comprehensive overview of the subject matter, covering both the theoretical and practical aspects. The author also mentions that the book is written in a clear and concise style, suitable for both students and professionals alike.

The second part of the document is the main body of the text, which is divided into several chapters. Each chapter covers a specific aspect of the subject, providing a detailed analysis and discussion. The chapters are:

- Chapter 1: Introduction to the subject matter.
- Chapter 2: Theoretical foundations and principles.
- Chapter 3: Practical applications and case studies.
- Chapter 4: Current trends and future prospects.
- Chapter 5: Conclusion and summary.

The third part of the document is a bibliography, listing the sources used in the book. This includes books, articles, and other references that provide additional information and support for the content of the text.

The fourth part of the document is an index, which provides a quick and easy way to find specific information within the book. The index lists the page numbers for each topic, allowing the reader to navigate the text efficiently.

Finally, the document concludes with a list of appendices, which contain supplementary material that is related to the main text but is not essential for understanding the core concepts. These appendices provide additional data, examples, and details that can be useful for further study and research.

upper arm, and from <sup>there</sup> crosses the track to a corresponding arm on opposite pole. Wire #4 which is the second power-limiting wire, rises from point "C" which is on a level with the dead end eye bolt in lower arm, to the height of insulator on the same arm, thence to point "D" from where it rises to the level of the eye bolt through the upper arm and from there crosses the track to a corresponding eye on the other pole. The two feeders, where two are encountered are tied together for some distance beyond the pole, so as to gain clearance, and are then dead-ended on an eye bolt through the pole itself; from the clamp which holds the feeder the two cables are brought to a similar clamp attached to an eye bolt 90 degrees from the first and from there carried to the other pole. The two signal wires, #2 and #3, are dead-ended on two pin cross arms four feet below the upper buck arm and wire #2 rises from point "E" to the upper arm insulator level "E' ", crosses the insulators on these arms and drops at "F" to crossing span height. Wire #3 rises at point "G" to height of the signal insulators on the same arm and from point "H" again rises to point "H' " at crossing span height. The supplementary negative is dead-ended on the adjoining poles on either side of the crossing span and is carried under ground from one pole to the other. This arrangement of crossing the wires



from one side of the track to the other requires only one additional pole and yet allows a clear side of each pole for climbing.

The overhead construction at passing tracks and industries, drawing ED 147, provides a trolley and <sup>messenger</sup> anchorage at one end of the passing track as shown at the right of the drawing. If the distance between head block of passing track and head block of industry track is greater than 700 feet, the upper scheme is used which provides for the dead-ending of one of the main line trolleys and carrying the other trolley and the messenger through to the passing track, while on the main line two other trolleys and one messenger are dead-ended, then run through to a point where the passing track again meets the main line, at which point the main line trolleys and messenger are insulated and brought up to span height, then drops down to trolley height in the next section, thus providing an air gap at each end of the passing track. Opposite these points are feeder switches so that the entire section within the passing track limits, whether it includes an industry plant <sup>track</sup> or a big yard, can be cut off from the rest of the system. The trolley and messenger for the industry track are separate wires dead-ended at either end of the industry.



In places where the distance between the passing track and industry head blocks is less than 700 feet the main line trolleys and messenger are brought up to span height near the passing track switch point, then dropped down to trolley height on the passing track and run in this manner to the industry switch, at which point one trolley is swung over to the industry and picks up a messenger, which is dead-ended near that point. Two separate trolleys and messengers are strung from the main line track within the passing track limit. A 1/2" steel guy and a 1" anchor rod is used for the head guy of each trolley and messenger dead end, thus where one trolley and one messenger, or two trolleys are dead-ended on one pole two 1/2" guys are used with two 1" anchor rods.

At points where substations are located within yard or passing tracks limits, as at Morel, Janney, Eustis, Josephine, Summit and Two Dot on the East end, the air brake in the main line comes opposite the substation, drawing ED 150. The wires are picked up from trolley height at point "A" for the line East and at point "B" for the line West of the substation, East being at the right end of the drawing, to span height so that as the pantograph on the locomotive passes this section it will travel from one set of contact wires



over to the second set without any appreciable movement of the collector. The tracks other than the main line are insulated from the latter by strain insulators inserted in the cross span, and these tracks are energized with power supplied through a switch in the substation. The arrangement at either end of the passing track is similar to that shown at the left of drawing ED 147, except for the span insulation.

#### Transmission Line.

The transmission line is of wood pole construction, of the suspension insulator type. On all the simple structures the insulation consists of six-unit strings of disk insulators, while the dead end structures have seven-unit strings.

The transmission wire is 2/0, seven strand, hemp core, copper, and the ground wire is 3/8" S. M. steel strand. Sag and dynamometer curves were made for use in stringing the cable, drawings ED 163 and 164, and are based upon a condition of 1/2" ice on the wire, 3-1/3 pounds per square inch wind pressure and zero degrees Fahrenheit temperature. This condition was found after a good deal of calculating to be the most severe, and yet probable for the country in which the line is built.



All of the wire is pulled by dynamometer, and spans up to 500' are pulled according to the curve for a 300' span, because the tension at ordinary stringing temperature for most spans within these limits varied so little, practically, that it was decided after tests were made to use the curve for a 300' span as standard up to 500'. Spans of 500' and over are pulled according to the curve for an 800' span or for particular spans in case of short distances between dead ends. It was also found that this could be used for spans on slopes of 5% and greater.

The standard tangent construction, drawing ED 21A, consists of two 4-3/4" by 5-3/4" by 11' 0" fir cross arms spaced 9 feet apart on the pole. The upper arm has one string of insulators while the lower arm carries the other two. On the upper arm, at the opposite end from the insulator, is attached the ground wire from which a tap is taken along the arm and down the pole terminating in a spiral on the butt of the pole for lightning protection. The distance between the wires is 9' on one leg and 10'2" on the second. This type of construction is also used on curves up to 1 degree or angles up to 3 degrees with a guy, for the spacing of the poles on a 1 degree curve is such that the angle on any one pole is not greater



than 3 degrees.

The right angle construction, ED 20A, has two offset arms 10'6" long, each on 3'0" and 7'6" centers with the pole. The long side of the arm carries an angle iron knee brace of 2" by 2" by 3/16" galvanized angle iron attached at its end and the point of attachment of the steel clevice is 2'3" below the under side of the arm. This is to give the required clearance of 3 feet from wire to any point on the pole or fixtures. In this case the pole would not foul the wire, but rather the angle iron bracket. On the short end of each arm is fastened a steel attachment casting, which is merely a cast steel channel with an eye at one end. The casting on the upper arm has attached to it a 3' length of 3/8" steel strand which in turn is clamped to the ground wire. The pole ground wire is connected to this short length of strand. The casting of the lower arm has attached to it the third string of insulators.

The left hand curve construction, instead of having two large offset arms, has only one and the top arm is only 6' long and has on one end of it an attachment casting for the insulator string while at the other end is a ground wire clamp, drawing ED 19A. The second arm is similar to that on the right hand curve construc-



tion. These curve construction poles are built for use on all curves over 1 degree and for angles up to and including 10 degrees, which is also the maximum angle on any one pole for any degree of curvature as the pole spacing is varied to suit the curves.

At points where the angle is from 10 degrees to thirty degrees a two pole structure, drawing ED 113, is used. The transmission line is dead-ended in both directions on these poles and there are two sets of strings of suspension insulators of seven units each. Each string is fastened to an eye bolt which passes through the double cross arm. A jumper cable is formed of the transmission wire between the two sets of insulators thus avoiding the cutting of the cable. The head guys are placed in line with the transmission wire produced and consists of eight  $1/2$ " S.M. steel guys in pairs of two, each pair having one anchor or deadman. Each pair of cross arms is tied together by one  $3/4$ " by 18" spacing bolt, four  $3/4$ " by 18" spacing eye bolts, besides the through bolts in the pole.

For angles over thirty degrees still another type of pole arrangement is used, drawing ED 39. Instead of having cross arms on the poles, the wires are dead-ended on eye bolts in the pole and carried around the pole by a jumper. The



reason for the change from the other construction was that the arms would have to be excessively long so as to get clearance between jumper and pole. The ground wire is carried <sup>on</sup> the back side of one of the poles at the top, except where the wires cross the trolley, at which points the ground wire is dead-ended on adjoining poles to the crossing span. The tension per square inch in the cables of the crossing span is less than normal so as to add an extra factor of safety.

At certain points of the transmission line, the pole construction, drawing ED 113, has been used, altho the angle at that point was less than thirty degrees. Where such is the case, it has been due to an abrupt change in the ground profile, at which point the insulators would have been picked up if a pole of moderate length were used. Where this would occur on tangent work the two pole structure, drawing ED 112, is used, which is the same as the other one except for the length of the cross arm, being 13'6" on the angle pole and 13'0" on the tangent.

Where spans are encountered of such a length as to put a weight of 450' of wire or more on each point of support on the pole double arms are used and the pole is side guyed by two 3/8" S.M. steel guys.



The 450' of wire can either be made up, as shown on drawing ED 33A, by having a 600' span adjacent to one 300' long, or it may be divided up in any manner depending upon ground profile and span lengths. On the mountain slopes conditions are encountered in some places where there is nearly the 450' of wire on one side of the pole alone. The amount of wire on any given pole is determined by plotting the pole height and then drawing in the curve representing the wire, and the distance from the pole to the lowest point in the loop of the wire, will give the amount of wire held on that side of the pole.

A fir block 5-3/4" by 12" and of a width to suit, usually about 7", is inserted between the two arms at each end and is fastened to the double arms by two 5/8" by 18" machine bolts. In the center of this block is drilled a hole for the suspension eye bolt for the insulator string.

Transmission poles are set on 11' centers wherever the line crosses above a telephone line, unless one of the dead end structure is used on each side of the telephone. The poles when spaced 11' apart, drawing ED 40, are of such a length that the low wire is 11' above top of telephone pole, so that if the transmission wire should break in this short span the wire could not swing into the telephone circuit. In addition to this, each of the two high line



poles have a twenty foot angle iron arm on them on a level with the top of the telephone pole. This arm, drawing ED 351, is grounded, by being connected to the wire on the side of the pole, so that if the transmission wire breaks in one of the adjacent spans, it will be grounded before it comes in contact with the telephone wires. A similar arm, but 22' in length is used on the two structures when the latter are poles next to the foreign circuit.

The power-limiting circuit provides a means of distributing the load at any one point on the trolley system amongst the substations so as not to overload any one station. The control system of the circuit will be in the load despatcher's office and provides a means of automatically changing the D.C. voltage on one station so that other stations will pump power to it. The actual method of control has not been given out by the Company up to this time and the wires are not even strung for it, so actually very little is known of its value.

Finis.



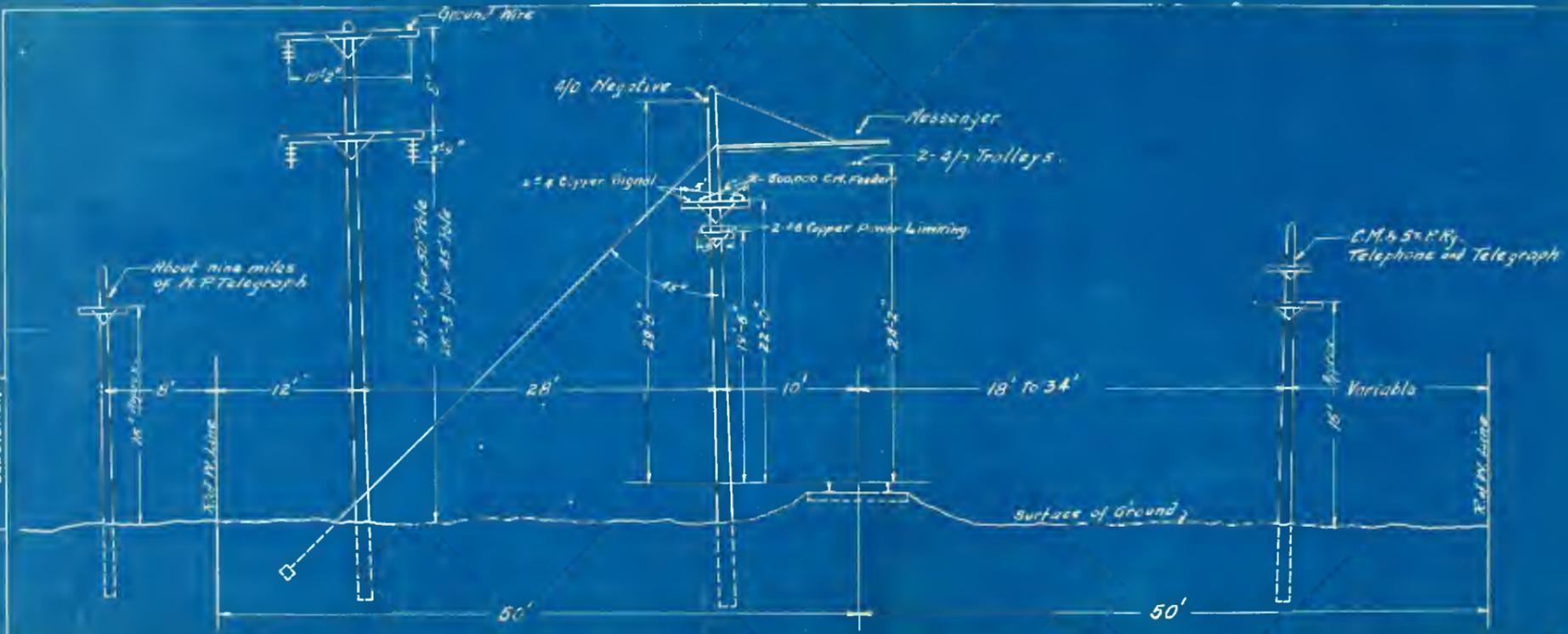


OX  
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Drawn By *J. J. [Signature]*  
 Checked By *[Signature]*  
 Approved *[Signature]*  
 ELEC. ENGR.



*Notes: Right of Way varies in width.  
 Transmission Line leaves R.  
 & W. at various points.  
 Revised: Oct 18, 1915.  
 Line flow of signal and power limiting wires.*

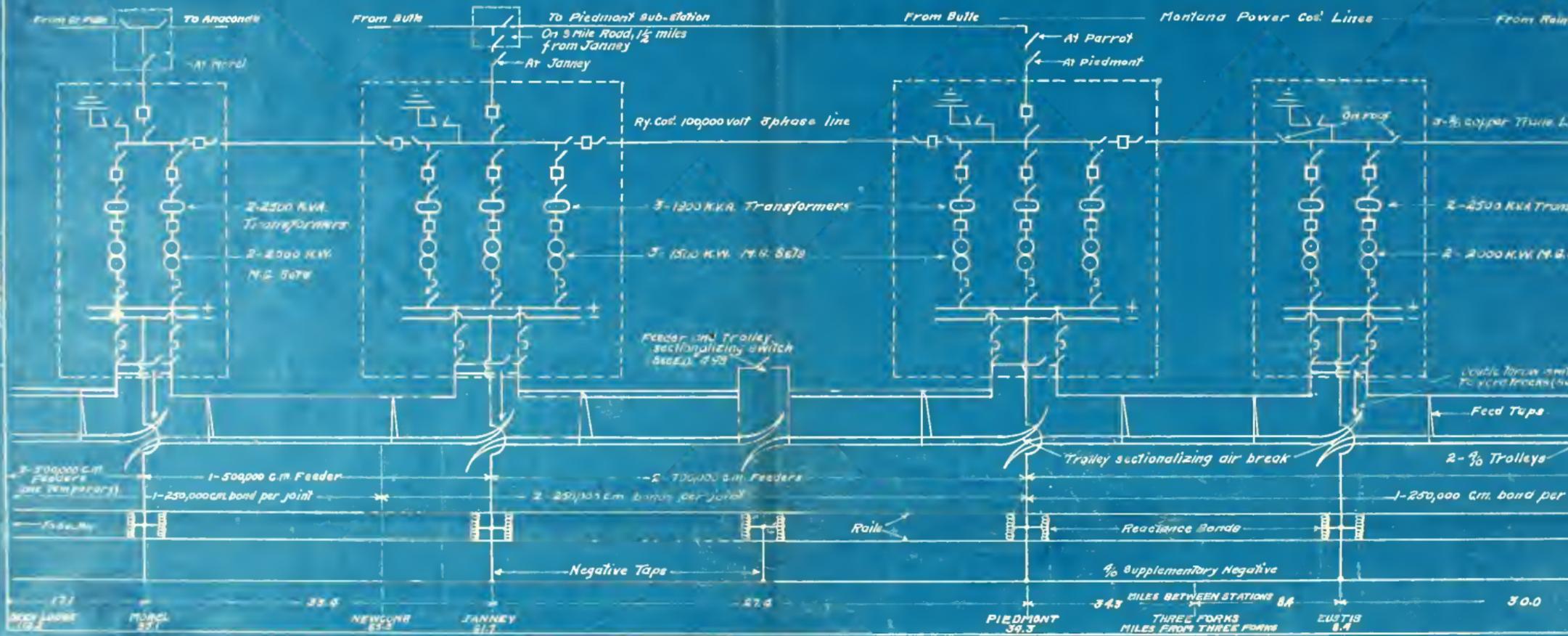
**C.M. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT  
**CONVENTIONAL XSECTION**  
 OF  
**RIGHT OF WAY WITH 100' WIDTH**  
 Butte, Mont. March 11, 1915  
 E. O. 108

MOREL

JANNEY

PIEDMONT

EUSTIS

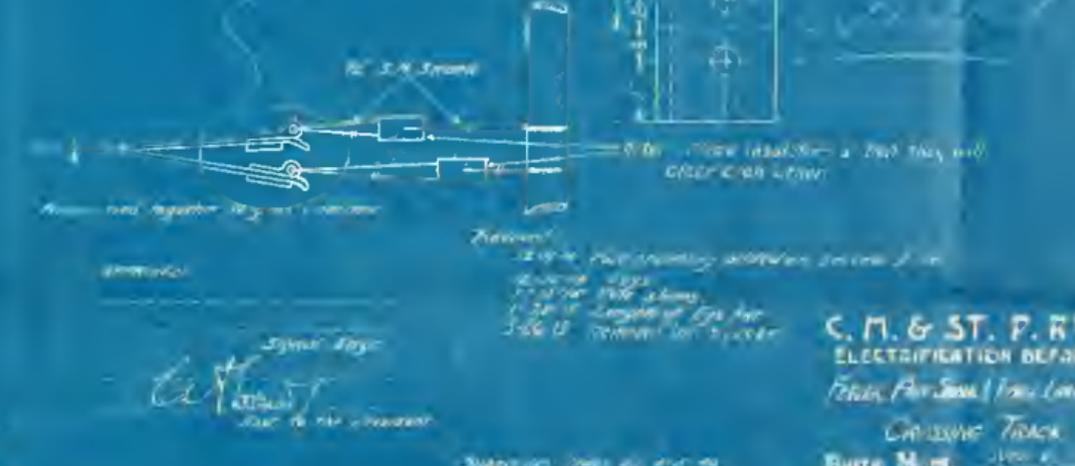
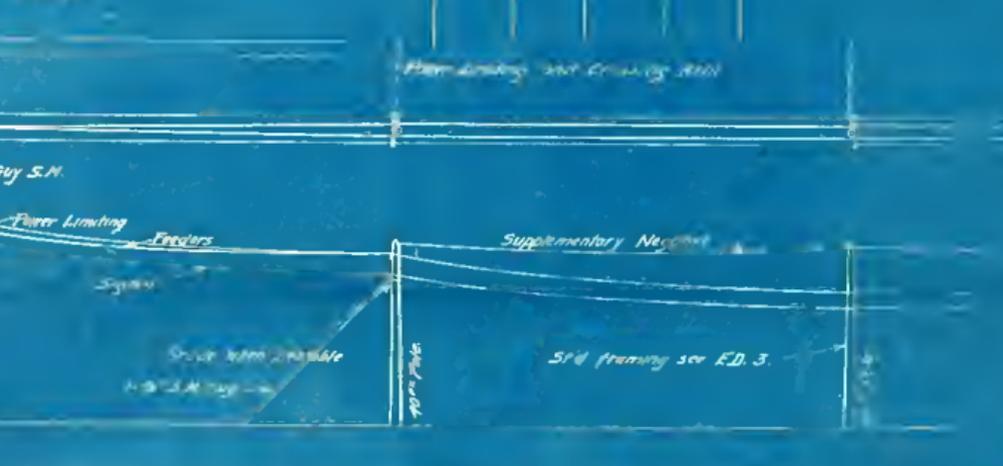
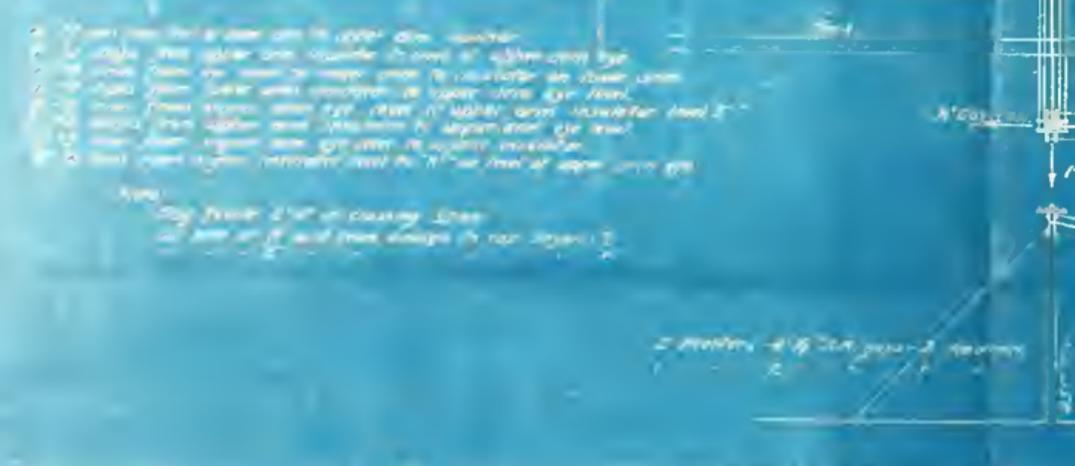
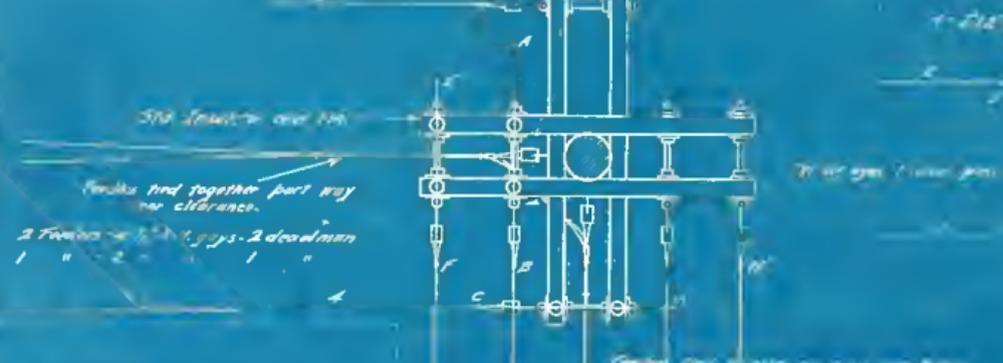








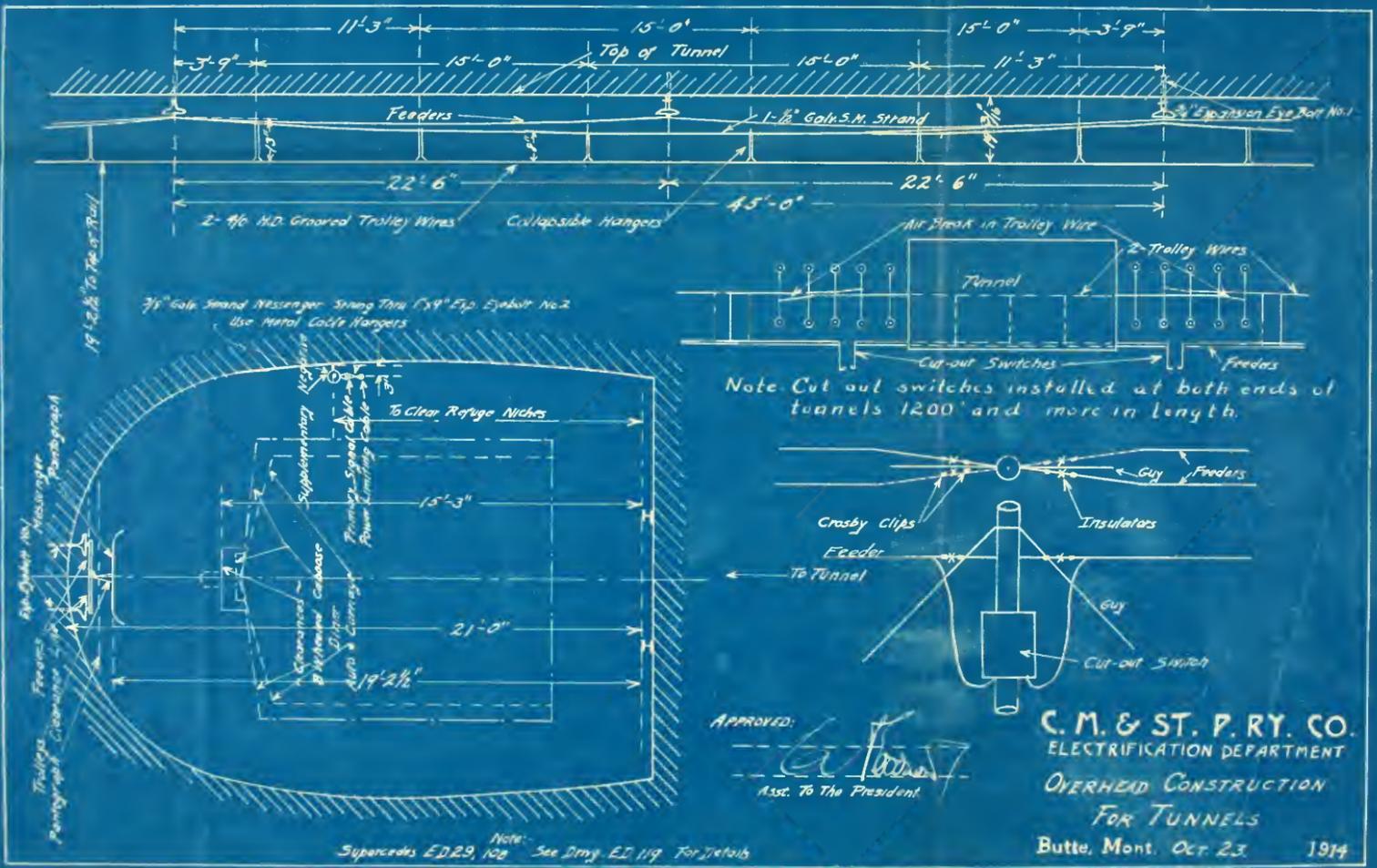




1. Overhead line to be used on the upper line.
2. The wire to be used on the lower line is to be of the same size as the wire on the upper line.
3. The wire to be used on the lower line is to be of the same size as the wire on the upper line.
4. The wire to be used on the lower line is to be of the same size as the wire on the upper line.
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6. The wire to be used on the lower line is to be of the same size as the wire on the upper line.
7. The wire to be used on the lower line is to be of the same size as the wire on the upper line.
8. The wire to be used on the lower line is to be of the same size as the wire on the upper line.

**C. M. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT  
 P.O. Box 1000, St. Paul, Minn.  
 CROSSING TRACK  
 BOSTON, MASS. 1914

Approved: *C. M. & St. P. Ry. Co.*  
 Chief Engineer  
 Approved: *H. J. ...*  
 Chief Electrician  
 Note: 8-15-15 Note on switches  
 Note: Crosby clips on the trolley wire as to wire size show from sketch to be 1/2" lighter than Crosby.



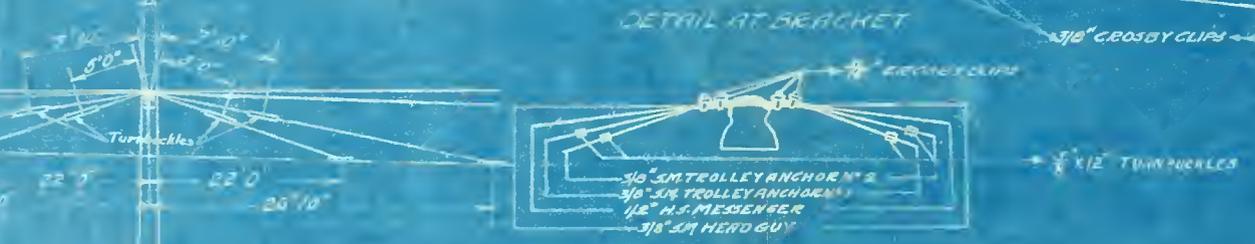
APPROVED:  
*[Signature]*  
 Asst. To The President

**C. M. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT  
 OVERHEAD CONSTRUCTION  
 FOR TUNNELS  
 Butte, Mont. Oct. 23, 1914

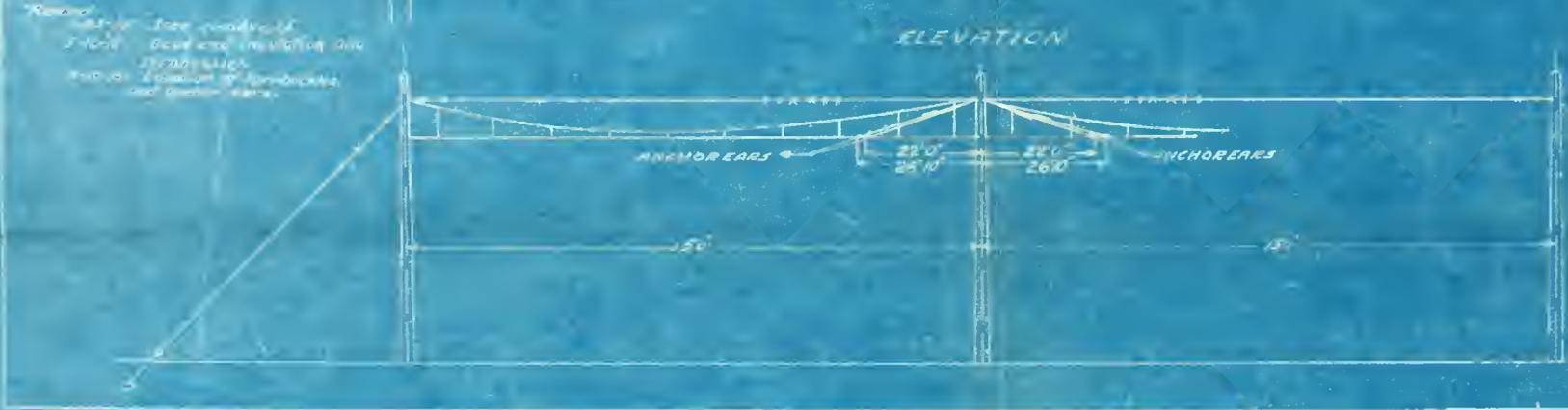
PLAN VIEW



DETAIL AT BRACKET



ELEVATION



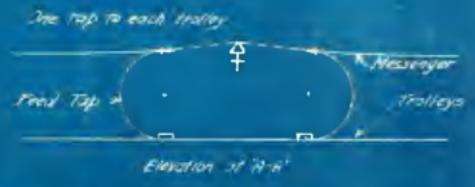
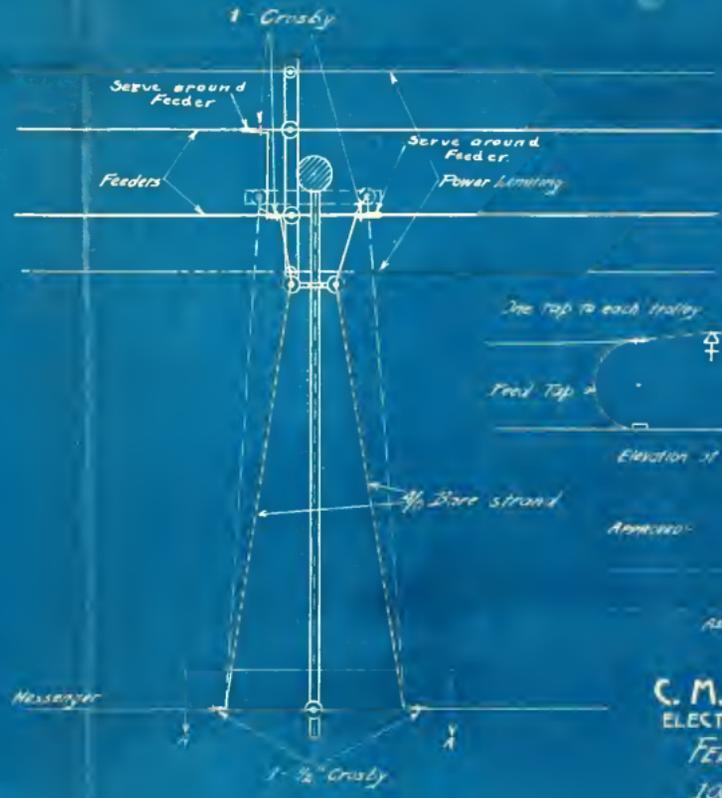
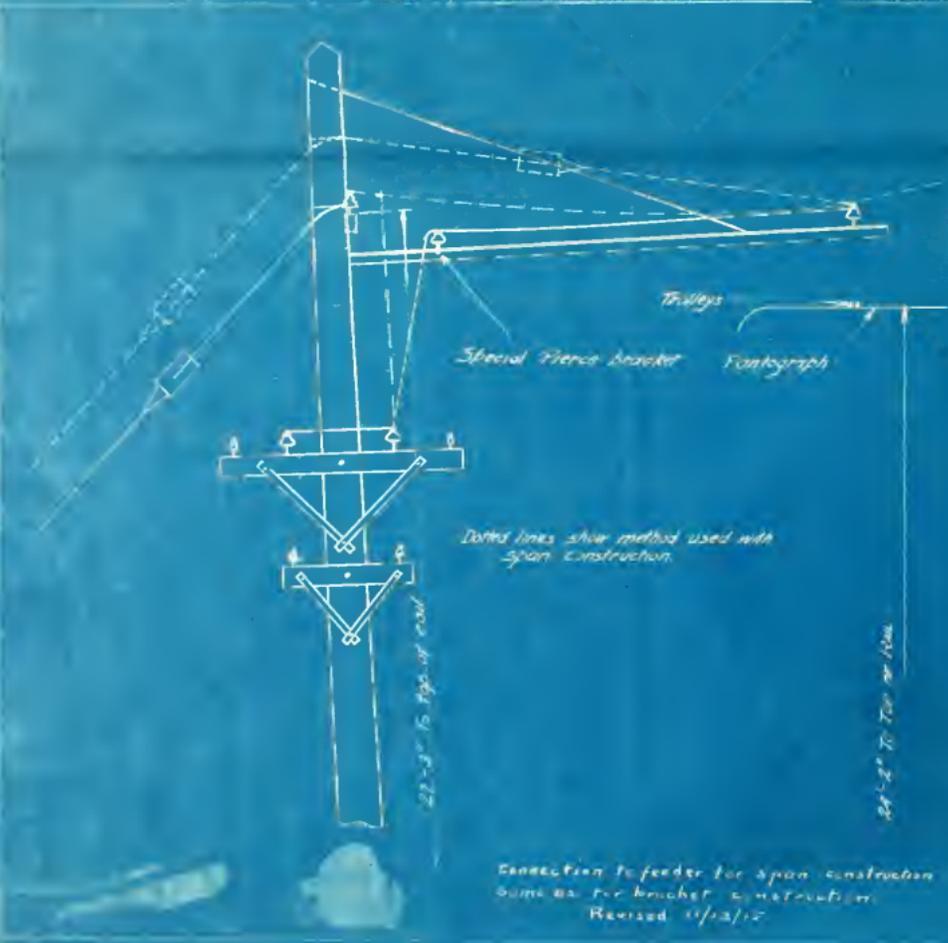
Notes:  
 1. All work to be done in accordance with the specifications of the U.S. Army and U.S. Navy.  
 2. All work to be done in accordance with the specifications of the U.S. Army and U.S. Navy.  
 3. All work to be done in accordance with the specifications of the U.S. Army and U.S. Navy.

APPROVED  
  
 CHIEF ENGINEER

C. E. ST. PAUL CO.  
 ELECTRICAL CONTRACTORS  
 TROLLEY & MESSENGER  
 ANCHORAGE

San Francisco, Aug. 25, 1914

Drawn by *H. L. M.*  
 Checked by *H. L. M.*  
 Approved by *H. L. M.*  
 E.L.S.G. ENGR.



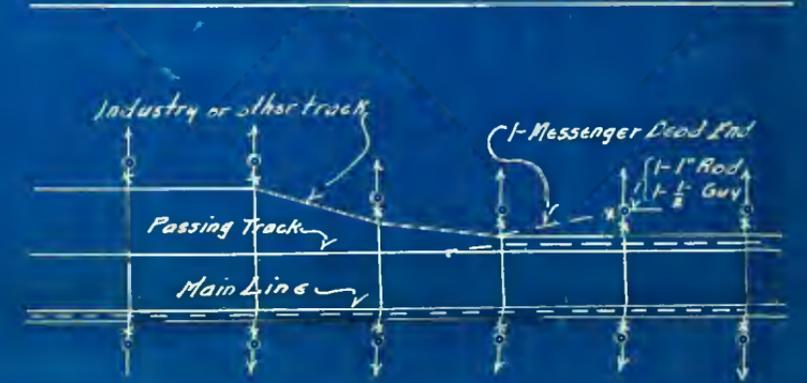
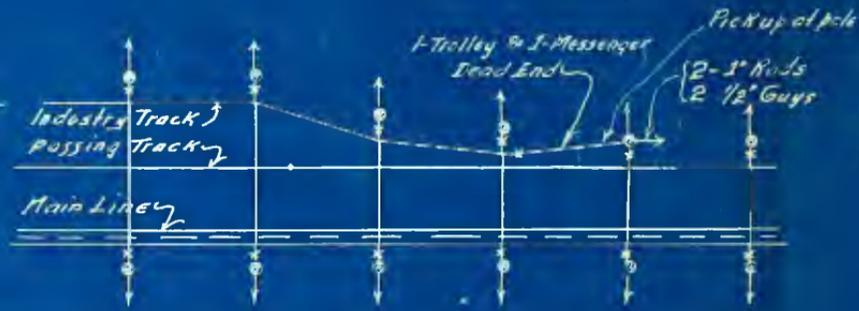
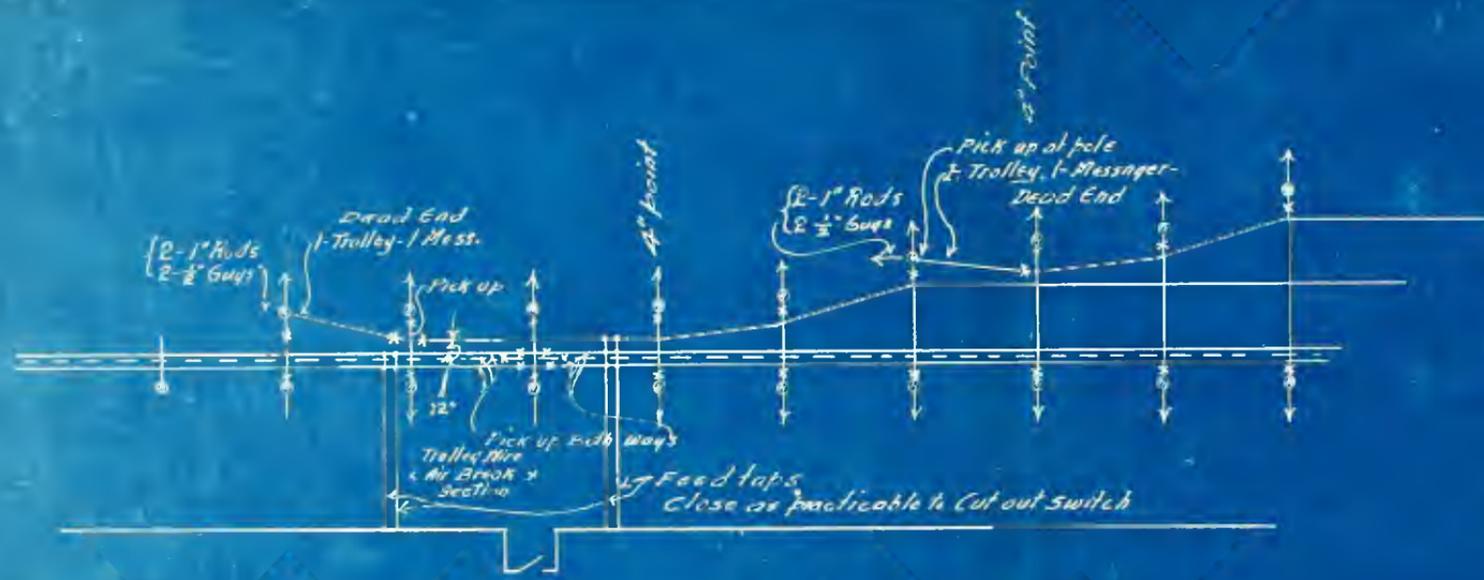
Approved:

ASBY TO THE PRESIDENT

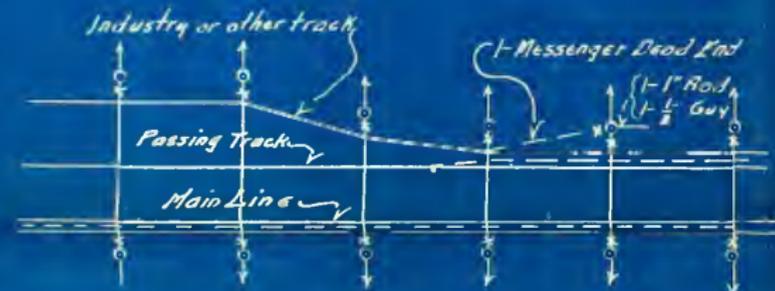
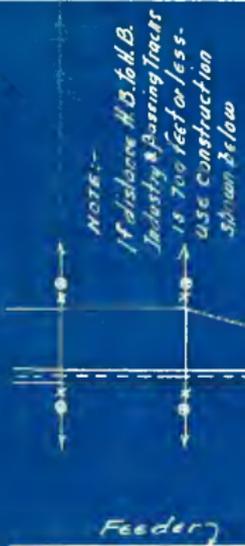
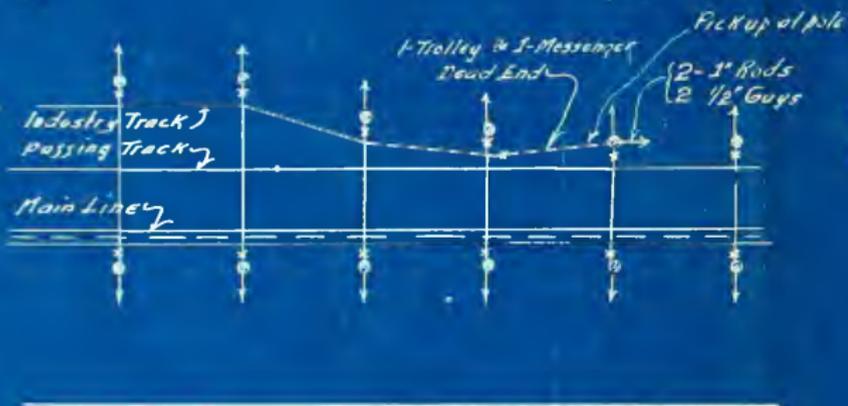
**C. M. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT  
 FEEDER TAPS  
 1000' APART  
 Butte, Mont. NOV 27 1914

ET 138

1115  
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Notes Revised 5-25-10. Insulation.



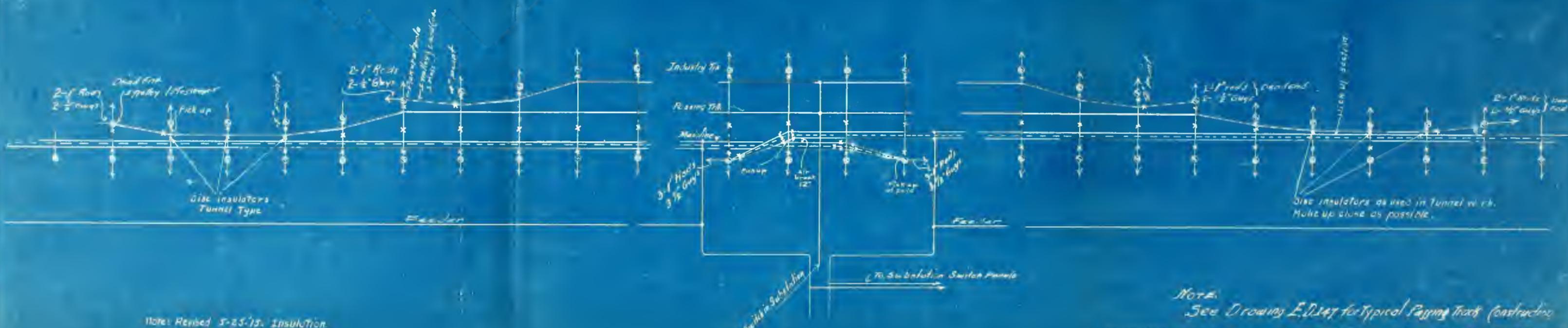
APPROVED

ASST. TO THE PRESIDENT

x = Insulation  
Not shown for 2495

C.M. & ST. P. R. CO.  
ELECTRIFICATION DEPARTMENT  
TYPICAL  
OVERHEAD CONSTRUCTION  
AT  
PASSING TRACKS  
Rolla, Mo., Jan. 11, 1915

E.D. 147



Note: Revised 3-25-15. Insulation.

NOTE.  
See Drawing E.D.147 for typical Passing track construction.

APPROVED

ASST. TO THE PRESIDENT

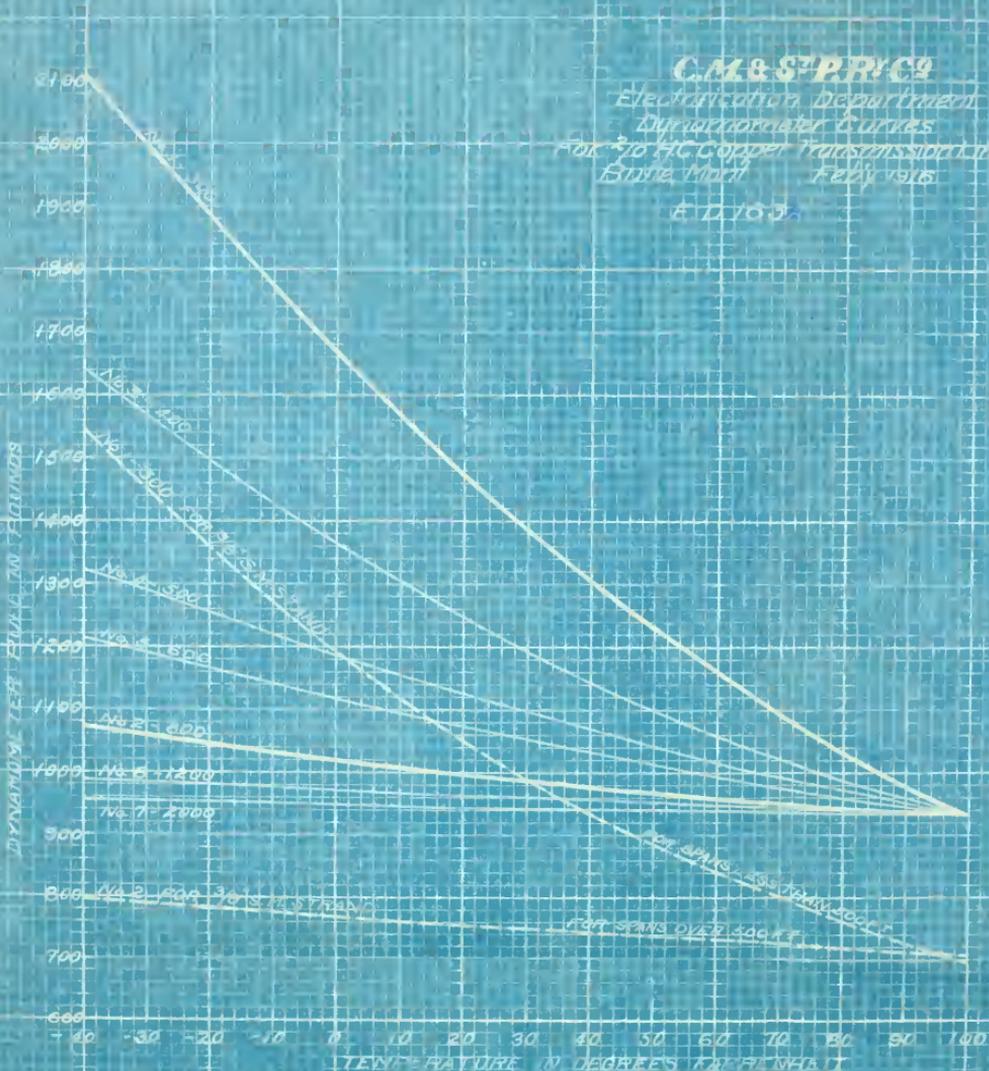
C. & ST. P. RY. CO.  
ELECTRIFICATION DEPARTMENT  
OVERHEAD CONSTRUCTION  
AT

PASSING TRACKS WITH SUBSTATION  
Buff, Mont. Jan. 25 1915

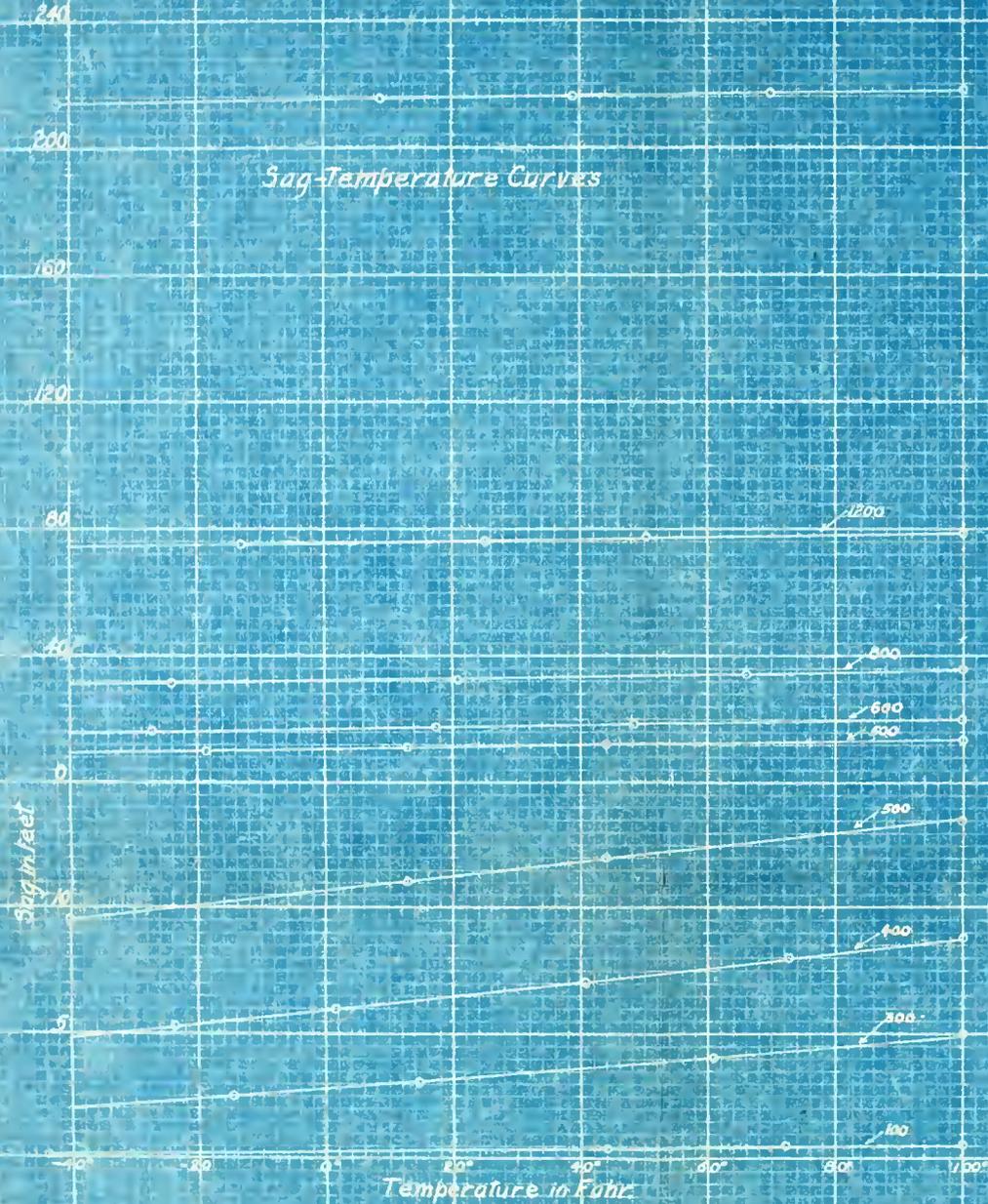
# C. M. & S. APP' CO

Electrical Engineering Department  
Differential Calculus  
Prob. No. 10. Copper Transmission Line  
Bryn Mawr Feb'y 1916

E. D. 1005



*Sag Temperature Curves*



**C. A. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT

*% Hemp Core  
 Transmission Line  
 Sag Curves.*

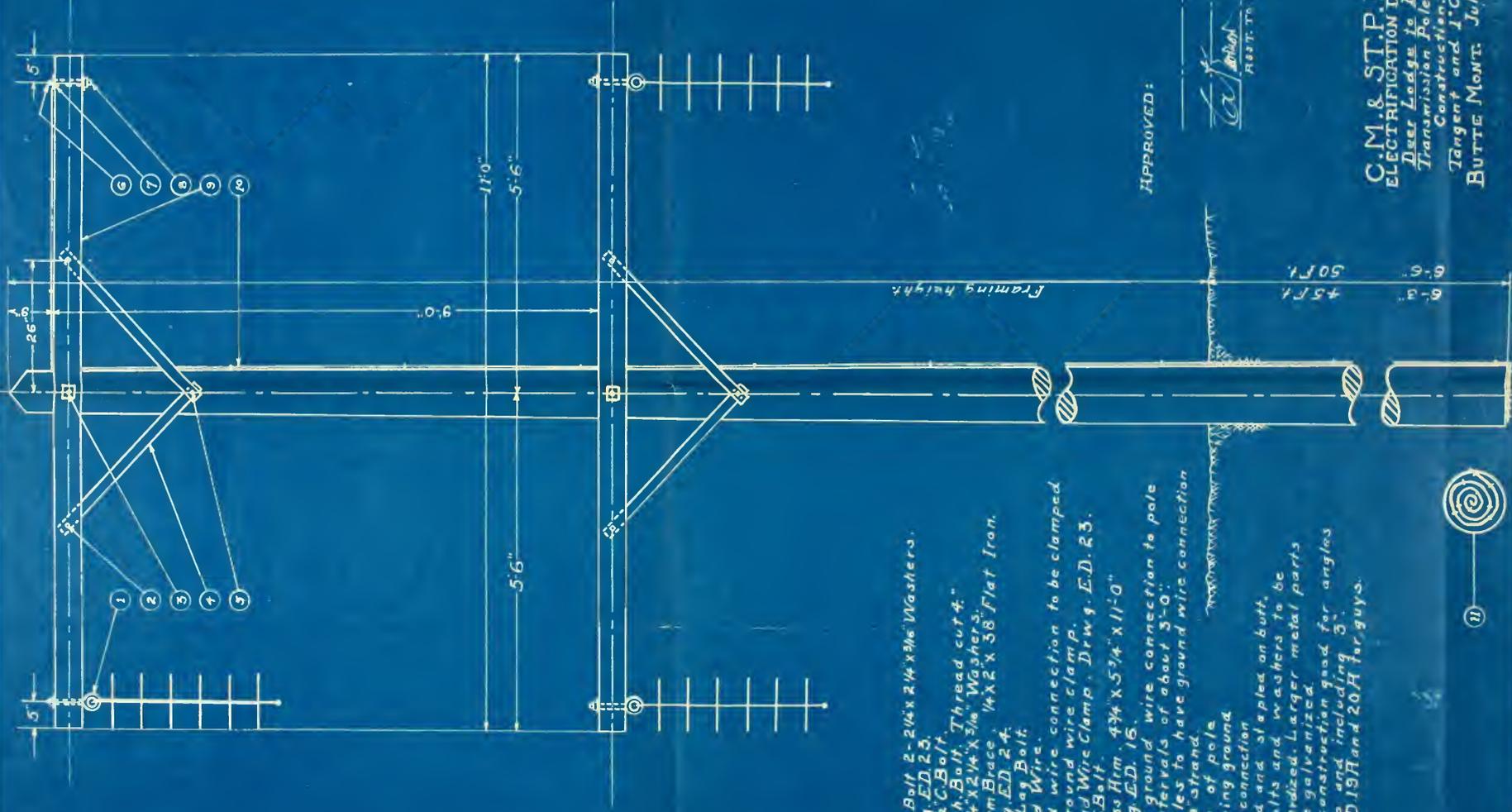
Batte, Mass. March 6 1915

E. D. 164

Assembly R.V.P.

Checked by [Signature]

Approved [Signature]  
ELECTRICAL ENGINEER



- (N)
- 1 --- 5/8" Eye Bolt 2-2 1/4 x 2 1/4 x 3/16" Washers. Drawg. E.D. 23.
  - 2 --- 3/4" 1 1/2" C Bolt.
  - 3 --- 3/4" Mach. Bolt. Thread cut 4". 2-2 1/4" x 2 1/4" x 3/16" Washers.
  - 4 --- Cross Arm Brace. 1/4" x 2" x 38" Flat Iron. Drawg. E.D. 24.
  - 5 --- 3/8" x 5" Lag Bolt.
  - 6 --- Ground Wire.
  - 7 --- Ground wire connection to be clamped in ground wire clamp.
  - 8 --- Ground Wire Clamp. Drawg. E.D. 23.
  - 9 --- 3/8" x 3" C Bolt. 4 1/4" x 5 1/4" x 1 1/2" Fir Cross Arm. Drawg. E.D. 15.
  - 10 --- Staple ground wire connection to pole at intervals of about 3'-0".
  - 11 --- Bottom of pole showing ground wire connection coiled and stapled on butt. Notes: All bolts and washers to be sherardized. Larger metal parts to be galvanized. Note: This construction good for angles up to and including 5'. Note: See E.D. 19H and 20H for guys.

APPROVED:

[Signature]  
RES. TO THE PRESIDENT.

6-3 45 FT.  
6-6 50 FT.

C.M. & ST.P. RY. CO.  
ELECTRIFICATION DEPARTMENT.  
Deer Lodge to Axtell.  
Transmission Pole Top  
Construction.  
Tangent and 1" Curves.  
BUTTE MONT. July 15 1915

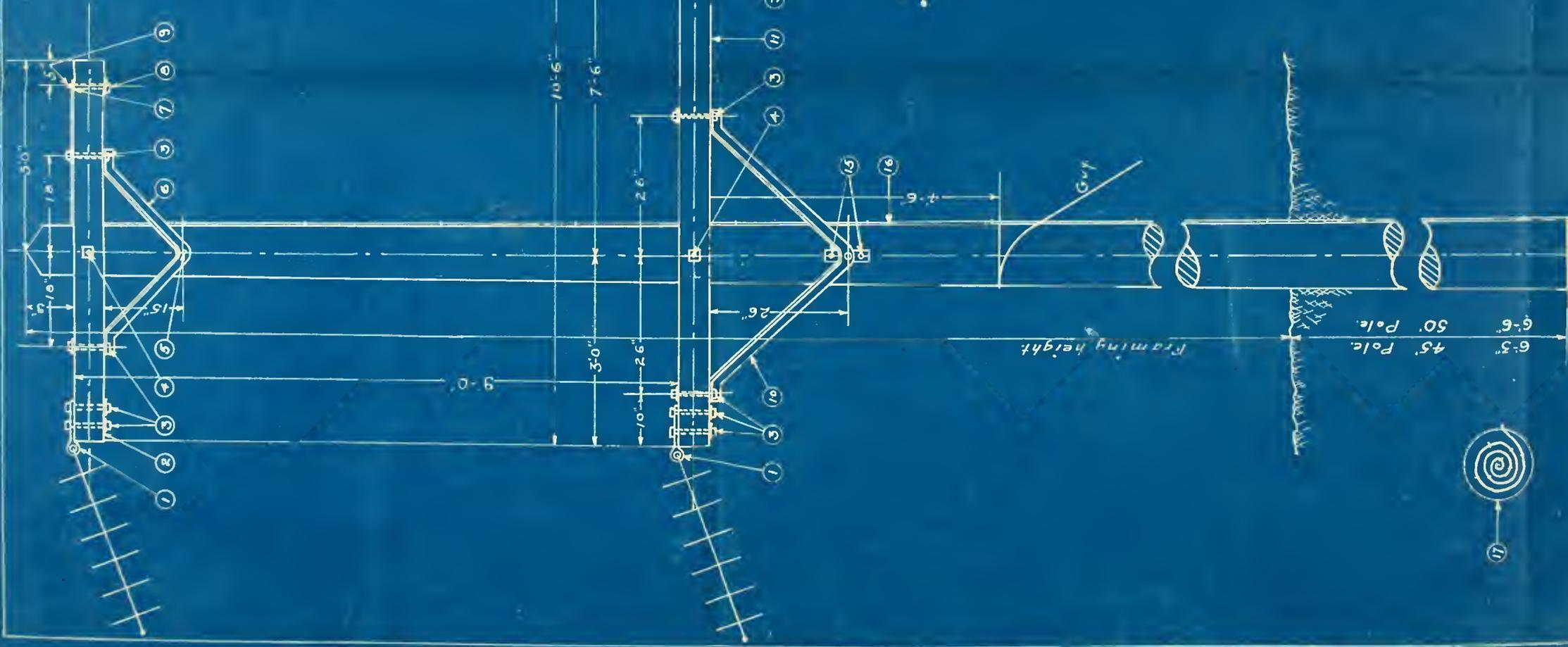


Drawn by E.V.D.

Checked by [Signature]

Approved by [Signature]

ELECTRICIAN



(M)

- 1 Attachment casting. Drawg. E.D. 23
- 2 Fir Cross Arm 4"x5 3/4"x6'-0" Drawg. E.D. 25
- 3 3/8"x 7" Mach. Bolts
- 4 3/4" Mach. Bolt. Thread cut 4:
- 5 2-2 1/4"x2 1/4"x 3/16" Washers
- 6 9/8"x5" Lag Bolt.
- 7 Cross Arm Brace No. 1. 2"x2"x 3/16" Angle. Drawg. E.D. 24
- 8 Ground Wire Clamp. Drawg. E.D. 23.
- 9 3/8"x8" C. Bolt
- 10 Ground Wire.
- 11 Cross Arm Brace No. 2. 2"x2"x 3/16" Angle. Drawg. E.D. 24
- 12 Fir Cross Arm. 4"x5 3/4"x10'-6" Drawg. E.D. 25
- 13 Clevis for Suspension Bracket. Drawg. E.D. 24
- 14 3/8"x6" Mach. Bolts.
- 15 Suspension Bracket. 2"x2"x 3/16" Angle. Drawg. E.D. 24
- 16 3/8"x5" Lag Bolts.
- 17 Staple ground wire connection to pole at intervals of about 3'-0". All poles to have ground wire connection of 3/8" strand.
- 18 Bottom of pole showing ground wire coiled and stapled on butt.

Note: All bolts and washers to be galvanized.  
 Larger metal parts to be galvanized.  
 Note: This construction good for angles up to and including 10°.  
 See Drawg. E.D. 21 A for 1° curves.  
 S.M. guy strand. On curves over 3° use 3/8" S.M. guy strand with pole shims and guy hooks.

APPROVED:

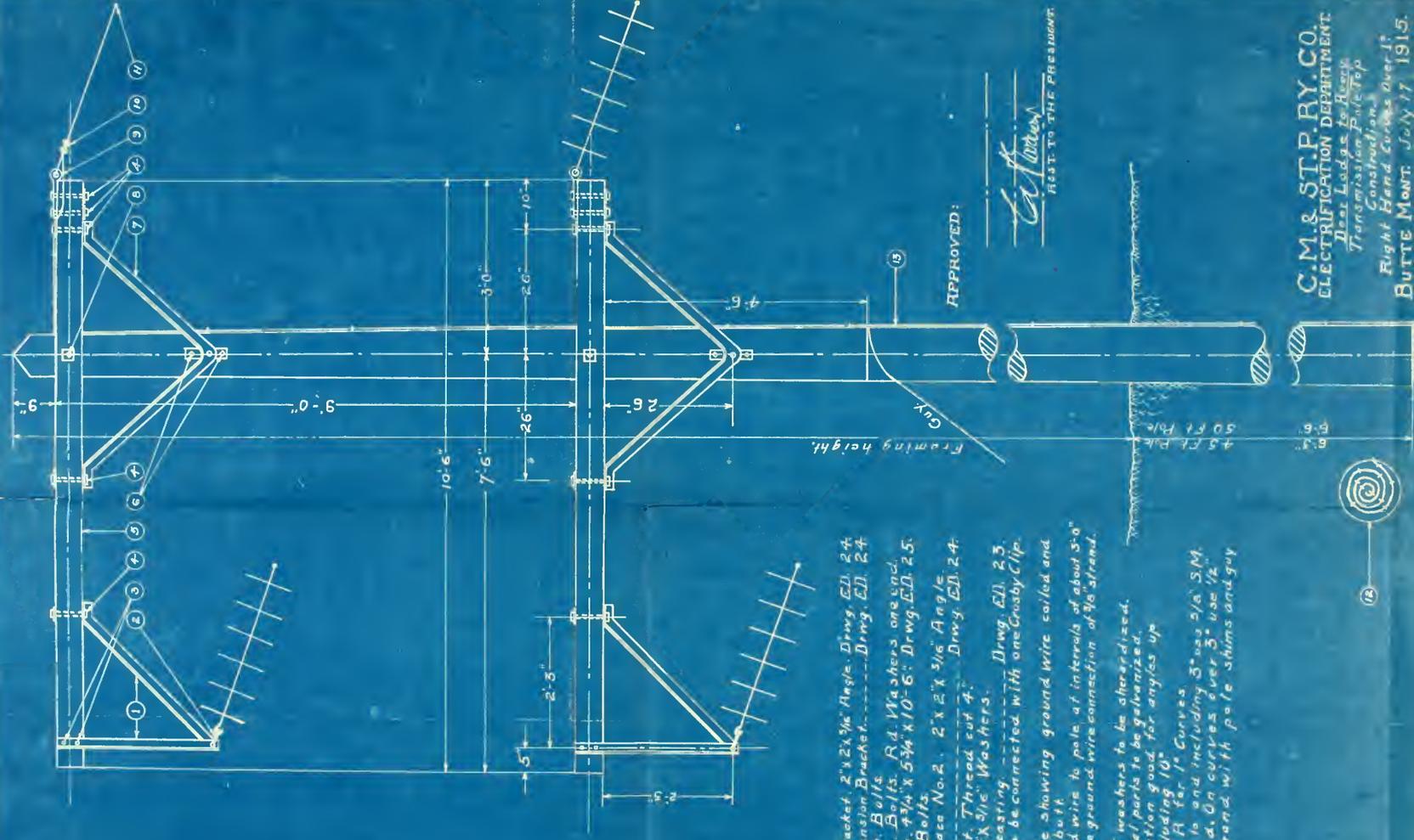
[Signature]

ASST TO THE PRESIDENT.

**C.M. & ST.P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT.  
 Deer Lodge to Hecy  
 Transmission Pole Top  
 Construction.  
 Left Hand Curves Over 1°  
 BUTTE MONT. July 19-1915  
 E.D. 19 A

Revised 10-7-15

Drawn by W. D. Crasby  
 Checked by W. D. Crasby  
 Approved W. D. Crasby  
 Title WGR



(16)

- 1--- Suspension Bracket, 2" x 2" x 3/16" Angle. Drawg. ED. 24
- 2--- Clews for Suspension Bracket.----- Drawg. ED. 24
- 3--- 5/8" x 7" Mach. Bolts
- 4--- 5/8" x 7" Mach. Bolts. R.4 Washers one end.
- 5--- 7" Cross Arm #3/4" x 5 3/4" x 10'-6". Drawg. ED. 25.
- 6--- 5/8" x 5" L. g. Bolts.
- 7--- Cross Arm Brace No. 2. 2" x 2" x 3/16" Angle. Drawg. ED. 24.
- 8--- 3/4" Mach. Bolt. Thread cut 4".
- 9--- 2- 2 1/4" x 2 1/4" x 3/16" Washers.
- 10--- Attachment casting.----- Drawg. ED. 25.
- 11--- Ground wire to be connected with one Crasby Clip.
- 12--- Bottom of pole showing ground wire coiled and stapled on built.
- 13--- Staple ground wire to pole, at intervals of about 3'-0".
- 14--- All poles to have ground wire connection of 3/8" strand.

Note: All bolts and washers to be galvanized.  
 Note: This construction good for angles up to and including 10".  
 See ED. 21A for 1" Curves.

Note: On curves up to and including 3" use 2 1/2" SM. guy strand. On curves over 3" use 1/2" SM guy strand with pole shims and guy hooks.

APPROVED:

*W. D. Crasby*  
 W. D. Crasby  
 ASST. TO THE PRESIDENT

Framing height.  
 GUY

5'-6"  
 4'-5" Pk  
 50 Ft. Fibre



(12)

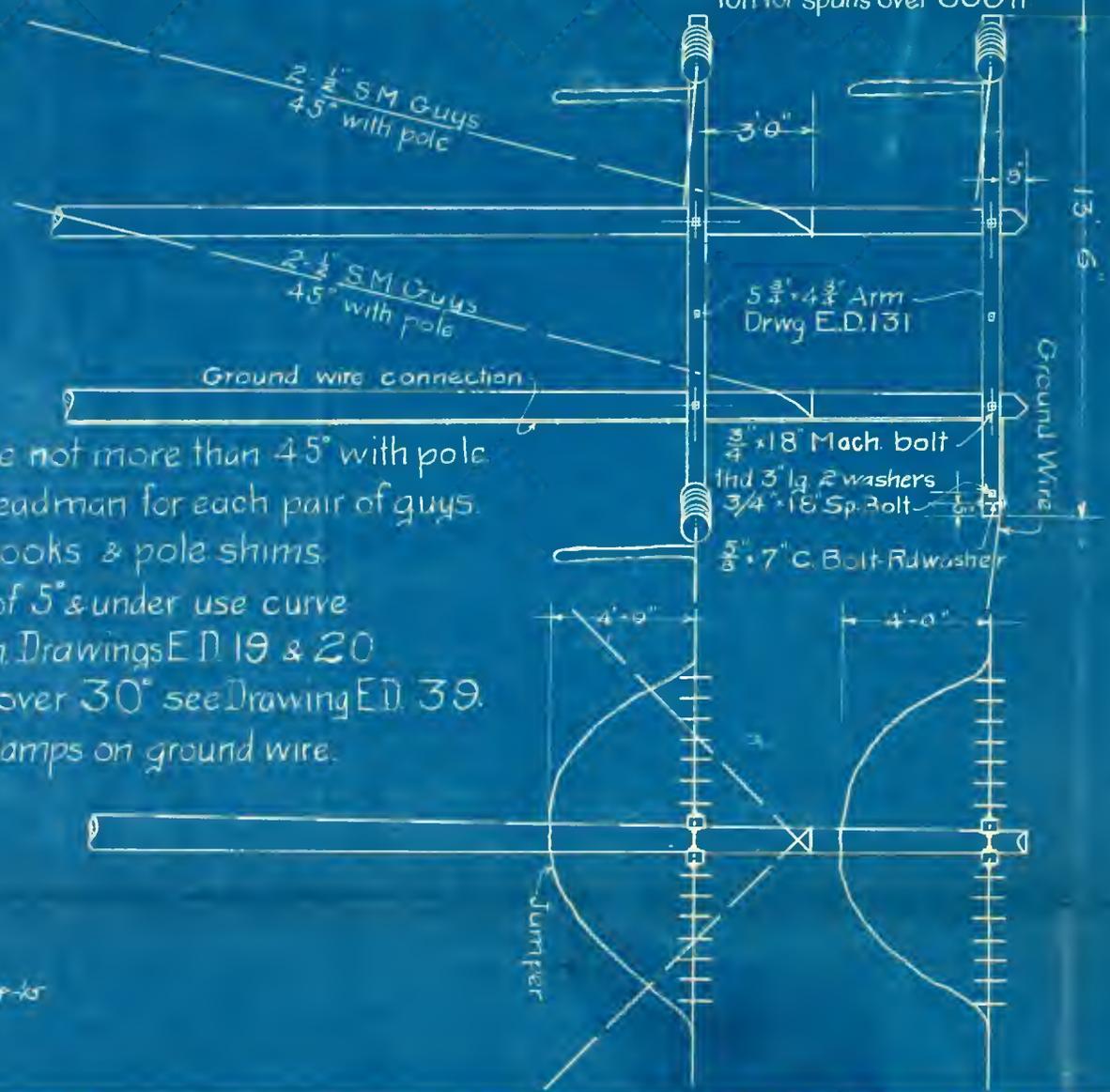
C. M. & ST. P. RY. CO.  
 ELECTRIFICATION DEPARTMENT  
 Chief Engineer  
 Transmission & Pole  
 Construction  
 BUTTE MONT. July 17 1915.

Revised 10-2-15

ED. 208

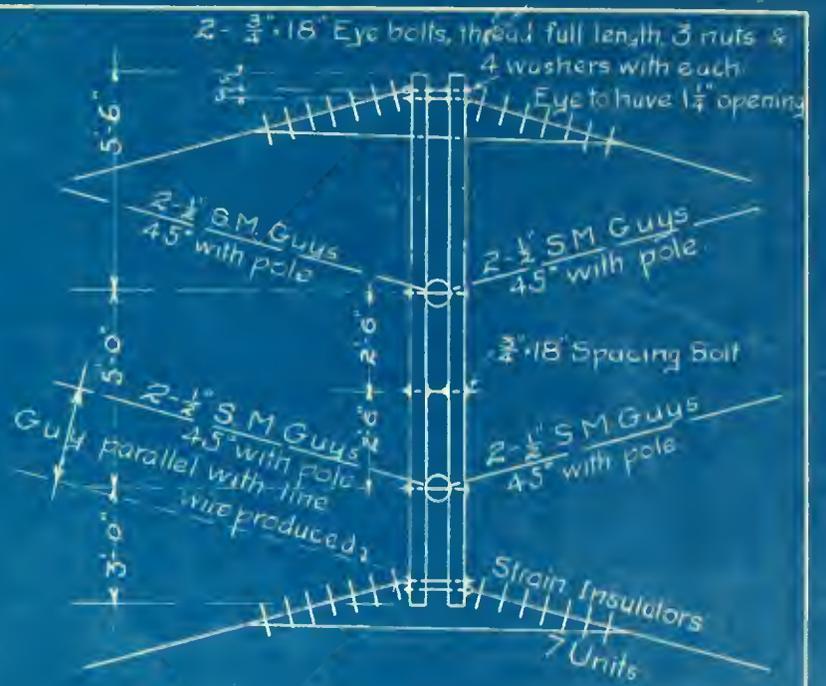
Drawn By *E. D. 113*  
 Checked By *R. Lewis*  
 Approved *[Signature]*  
 ELEC ENGR.

8ft for spans of 600ft and less  
 10ft for spans over 600ft



**Note**  
 Guys to be not more than 45° with pole  
 Use one deadman for each pair of guys.  
 Use guy hooks & pole shims.  
 For angles of 5° & under use curve construction. Drawings E.D. 19 & 20  
 For angles over 30° see Drawing E.D. 39.  
 Use two clamps on ground wire.

Revised *7/16-1-28-15*

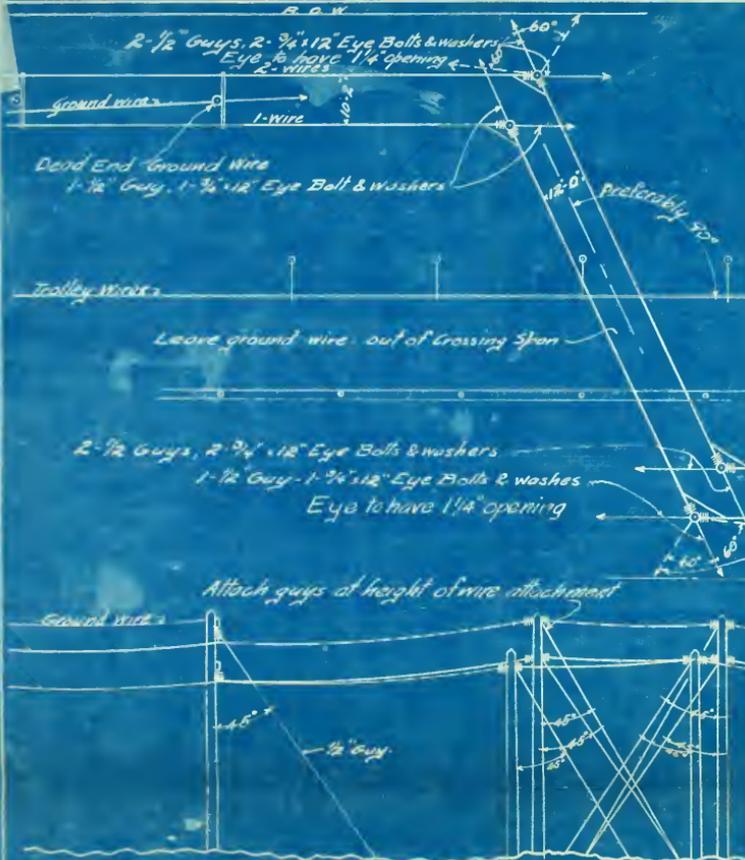


APPROVED:

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 ASST. TO THE PRESIDENT

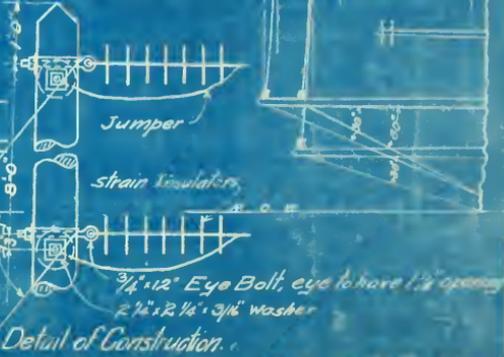
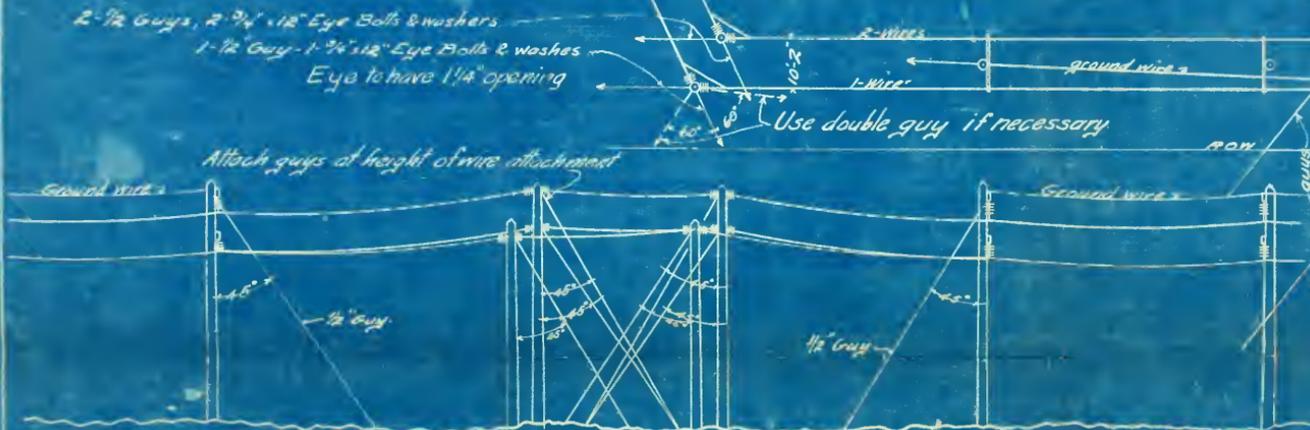
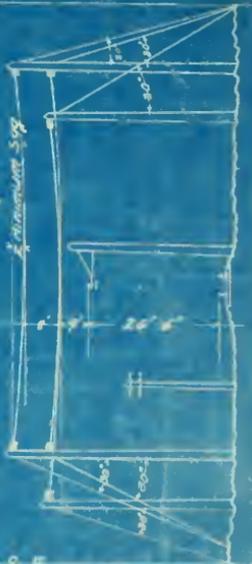
**C. M. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT  
 TRANSMISSION LINE CONSTRUCTION  
 FOR ANGLES OVER 10° & UP TO 30°  
 Butte, Mont. Oct 19 1914

Drawn by  
Checked by  
Approved  
ELECTRICAL ENGINEER



Note:  
 Select location of crossing so that poles will be as short as possible, at a cut is preferable.  
 Grade poles adjacent to crossing poles so as to avoid picking up insulators.  
 This drawing applies to tangent where R.O.W. is wide enough to give sufficient guy space - cross guys at 30° with pole. If R.O.W. is too narrow to give sufficient guying space for cross guys either on tangent or curves, deflect 5° (max) on each pole using 100ft span curve construction until sufficient guying spacers obtained. A clearance of eight (8) ft must be maintained between all wires.

Send a plan and profile of crossing in office for checking Strain Insulators to have Seven (7) suspension units.



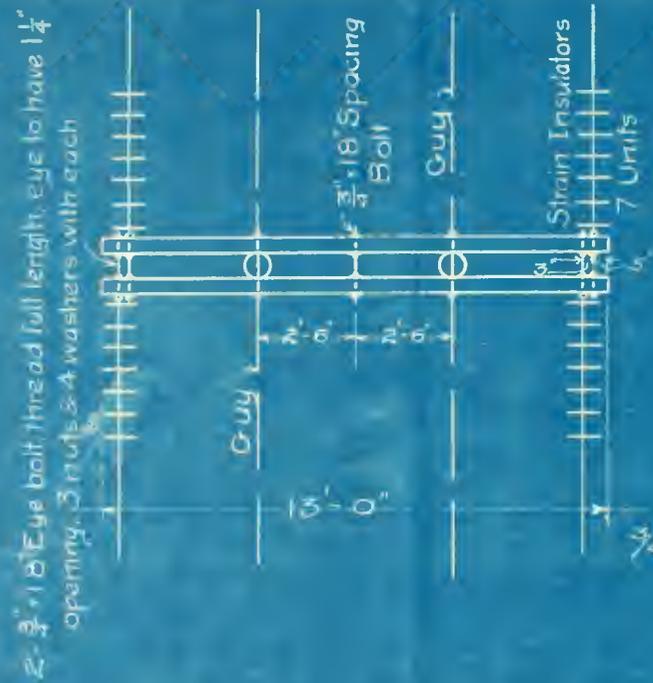
Revised:  
 Track overhead clearance  
 TITLE - 1-13-15  
 1894 - 1-25-15

Note: When used at angles other than at R.R. Kings add 8" to the short pole and carry ground wire on back side of this pole 8" above lower wire using 3/4" hook bolt for attachment.

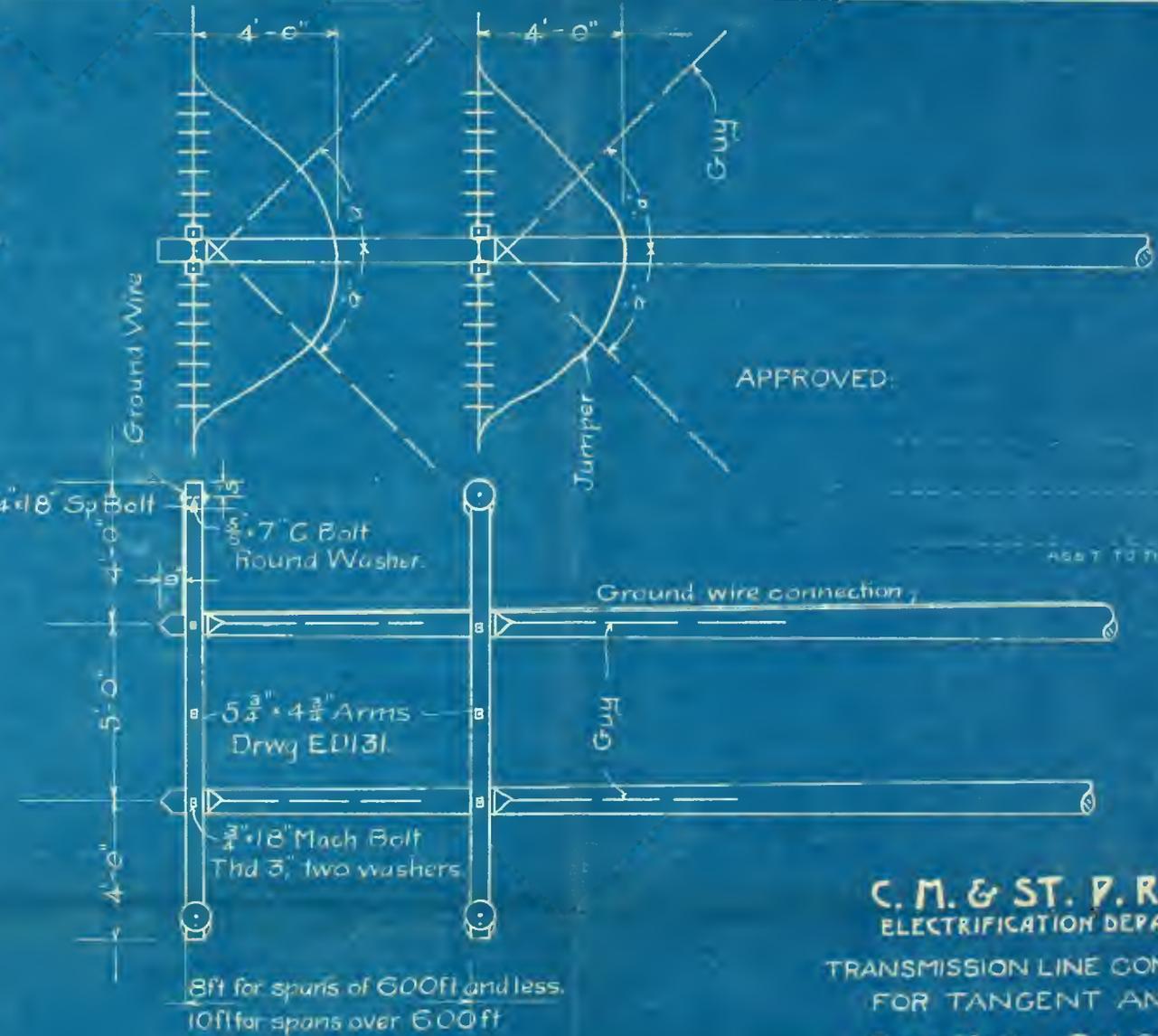
APPROVED  
 [Signature]  
 ASST. TO THE ENGINEER

C. P. & S. T. P. R. T. CO.  
 ELECTRICIANS AND ENGINEERS  
 TRANSMISSION LINE  
 CROSSING @ ANGLES OVER 30°  
 BOSTON, MASS. JUNE 23 1914  
 E. D. 39

Printed by *Ream*  
 Divided by *Ream*  
 Approved by *Ream*  
 E.L.C. ENG'G.



2- $\frac{3}{4}$ " x 18" Eye bolt, thread full length, eye to have  $\frac{1}{4}$ " opening, 3 nuts & 4 washers with each



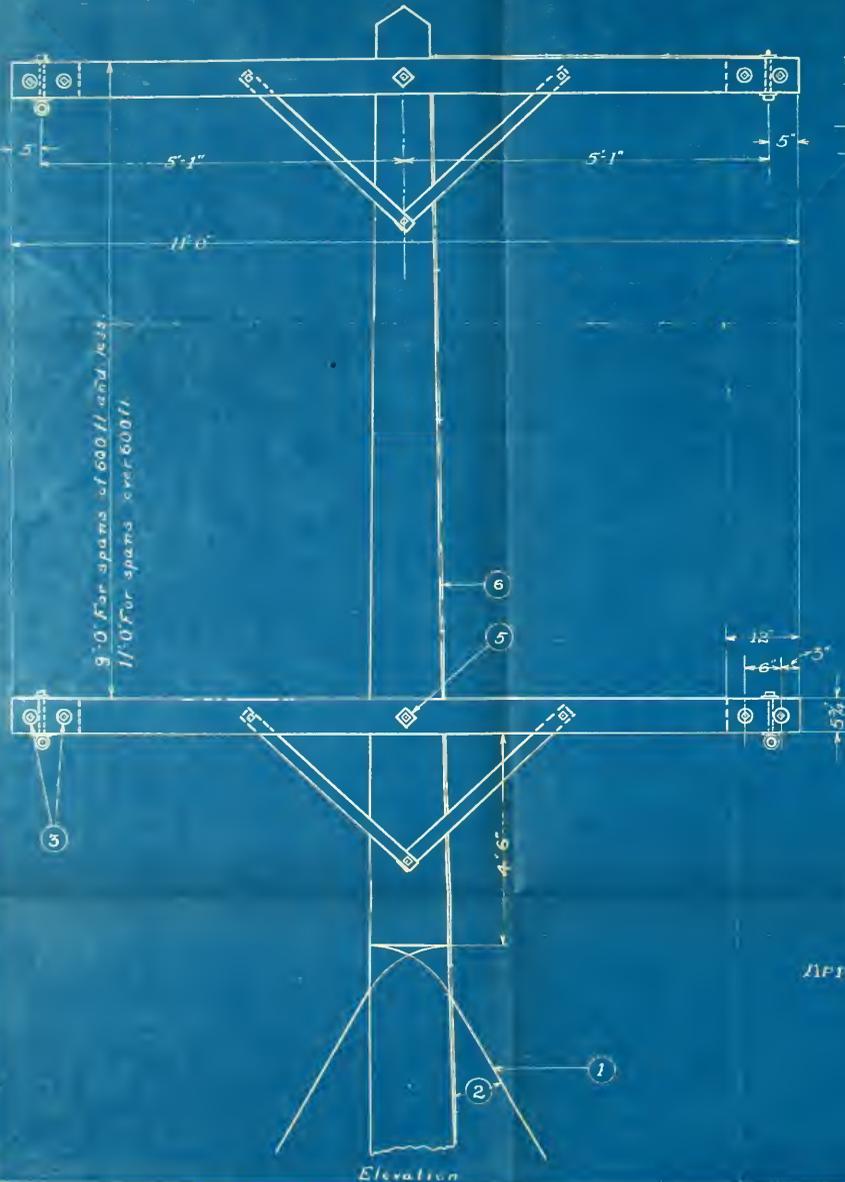
APPROVED:

ADD TO THE PRESENT

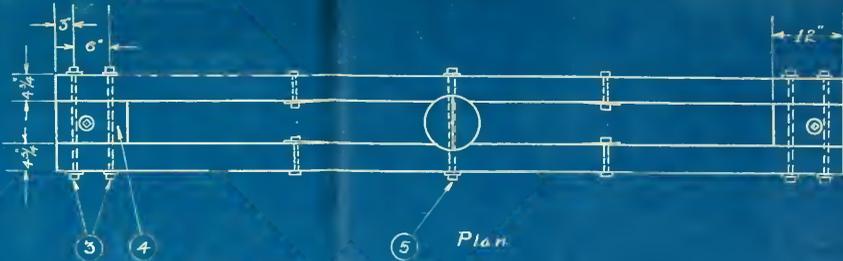
Note:  
 Angle 'a' not less than 35°  
 Use one deadman for each pair of guys.  
 " guy hooks & pole shims  
 " two clamps on ground wire  
 All guys to be  $\frac{1}{2}$ " S.M. strand

8ft for spans of 600ft and less.  
 10ft for spans over 600ft

**C. M. & ST. P. RY. CO.**  
 ELECTRIFICATION DEPARTMENT.  
 TRANSMISSION LINE CONSTRUCTION  
 FOR TANGENT ANCHORAGE.  
 Butte, Mont. Oct 20 1914

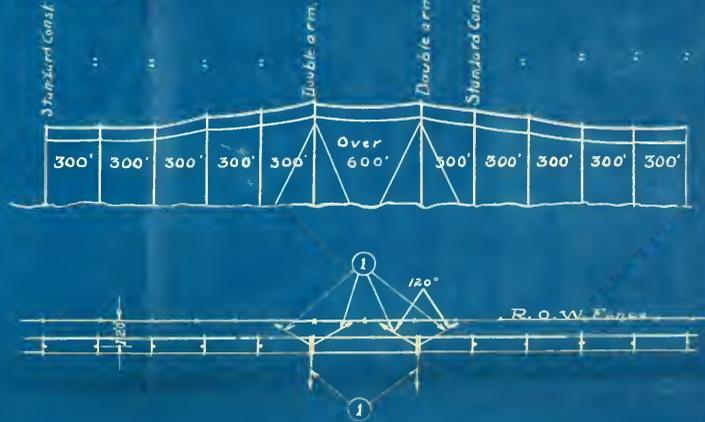


9'-0" For spans of 600 ft. and less.  
11'-0" For spans over 600 ft.



- 1. No. 3/8 3M. strand side guys.
- 2. Not less than 30"
- 3. 9/16 x 10" Mach Bolts, Thread 3" long  
2- 3/4" Rd washers with each
- 4. Fir block, 5 3/4 x 12", cut width to suit
- 5. 3/4 x 18" Mach Bolt, Thread 3" long.
- 6. Ground wire.

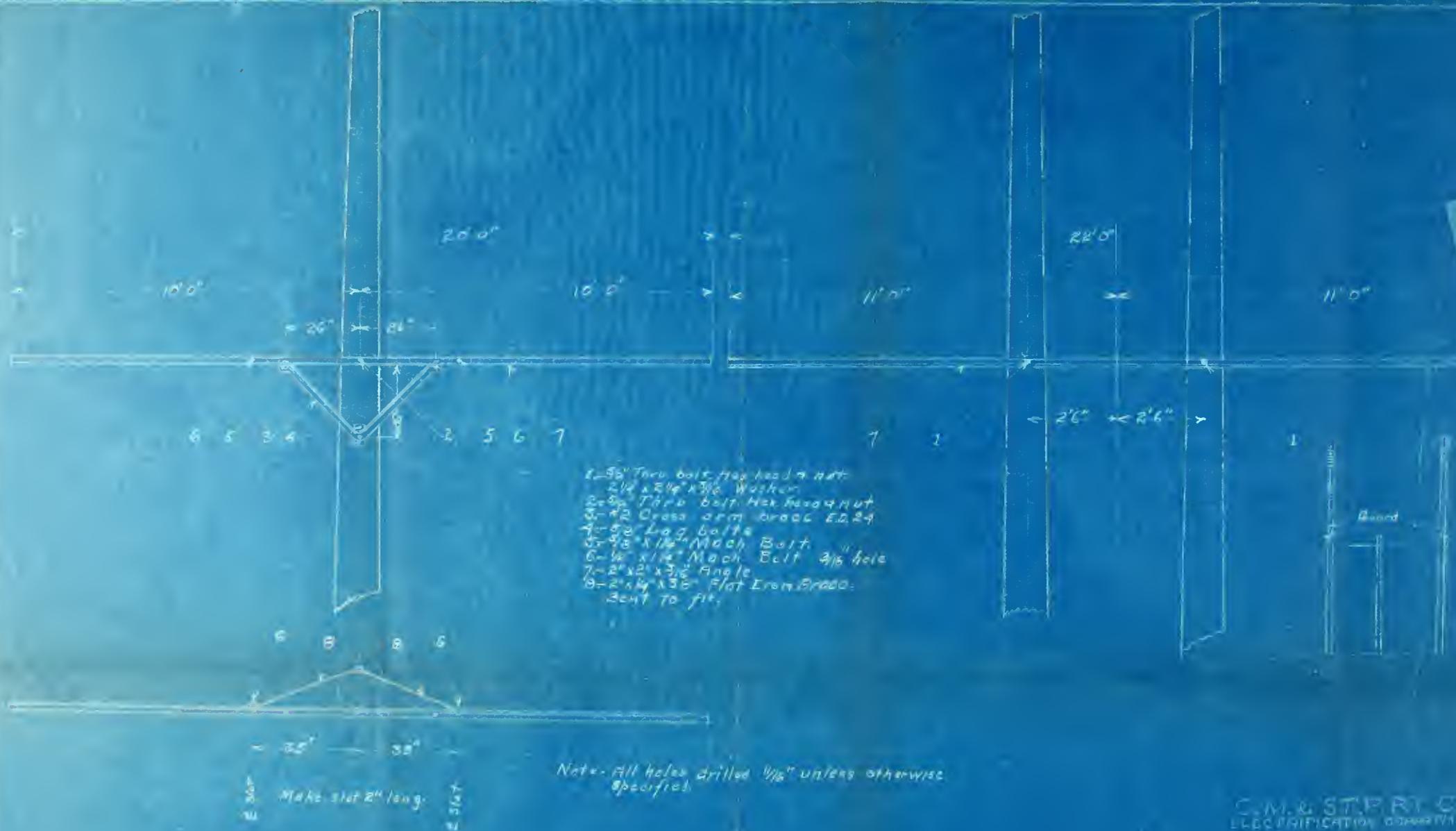
Note Double arm all poles supporting more than 450ft. of wire.  
Note Details not marked are the same as for standard tangent construction.  
See E. 21A



Drawn by: A. J. ...  
Checked by: ...  
Approved: ...  
ELECT. DIVISION

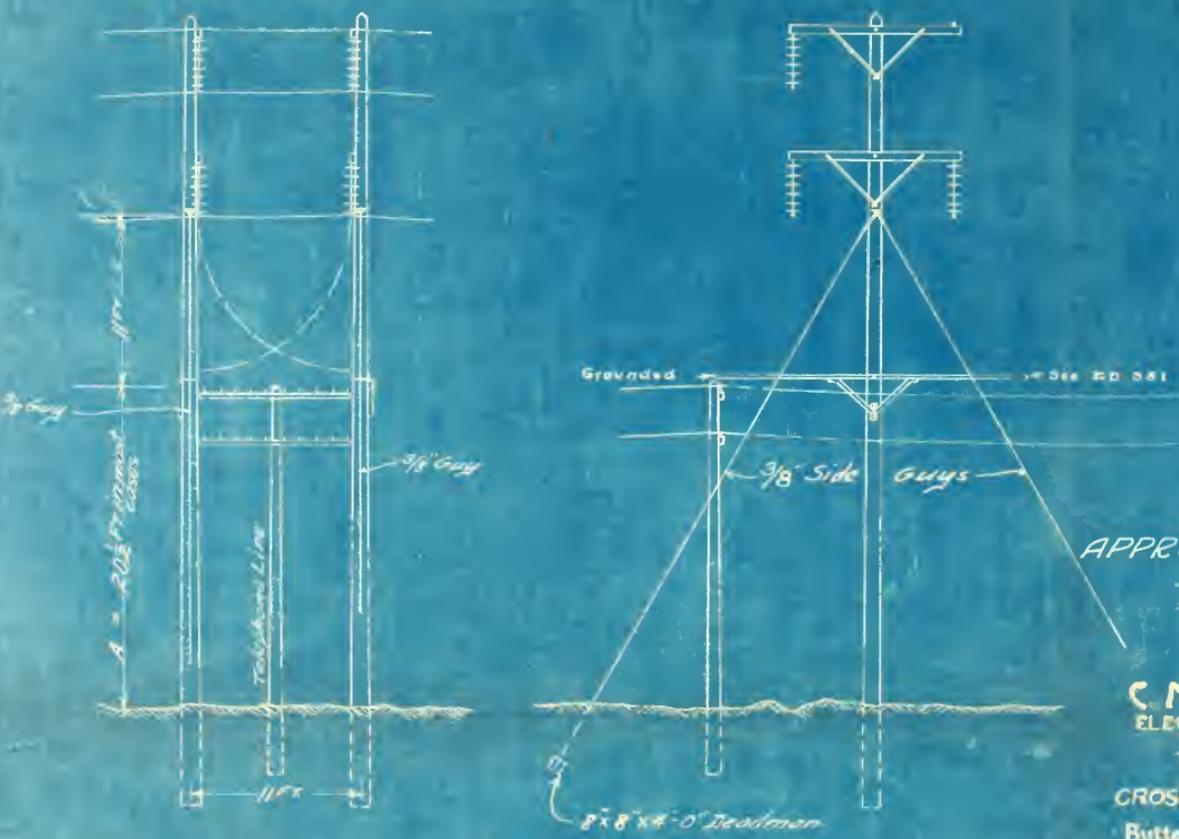
APPROVED: \_\_\_\_\_  
ASST. TO THE PRESIDENT

C.M. & ST.P. RY. CO.  
ELECTRIFICATION DEPARTMENT  
DEER LODGE TO AVERY.  
TRANSMISSION LINE  
LONG SPAN CONSTRUCTION.  
BUTTE, MONT. AUG 28 1915.



C. M. & S. P. RY. CO.  
 ELECTRIFICATION DEPARTMENT  
 IRONING BOARD USED ONLY  
 TRANSFORMER POLES WHEN R.L.  
 AT & T CROSSINGS ARE CROSSED  
 Same Mount Aug 28 1915  
 South Fork  
 E.D. 24

W. H. ...  
W. H. ...  
1914



APPROVED  
*[Signature]*  
 ASST. TO THE PRESIDENT

C. M. & ST. P. R. CO.  
 ELECTRIFICATION DEPARTMENT  
 TRANSMISSION LINE  
 CROSSING OVER TELEPHONE  
 Butte, Mont. JULY 3 1914

Revised 11/18/15 Ground Guard

ED 40

