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ELECTRIC SERVICE FROM RURAL TRANSMISSION LINES

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Electric Service From Rural Transmission Lines

By A. B. CAMPBELL

This bulletin has been prepared for distribution among farmers and those who are interested from the farmer's viewpoint, in extending electric service from transmission lines and central stations into rural communities. In the selection of the information which will be helpful to the farmer in securing electric service, questions which have been asked by the farmers in personal interviews and written inquiries have been closely followed.

Since this class of service is now in its development stage, some of the information contained in this bulletin may soon be obsolete. It is to be expected that some changes will be made in the form of contracts that are now being used and in the methods that are being followed in serving rural coustomers. These methods and the suggestions relating to them refer largely to Iowa conditions, and may not be applicable to certain other agricultural districts.

Technical discussions have been intentionally avoided for the reason that such discussions are not only of little value, but are often confusing to those who are not familiar with the problems connected with electrical distributing systems.

THE APPLICATION OF ELECTRICITY ON THE FARM

There are many ways in which electricity may be used to advantage on the modern farm, and it should be realized at the start that most of these applications must be made, if the service is to be had at a reasonable cost. It will doubtless require considerable time before the farmer can arrange to utilize electric power to its greatest advantage, but as soon as the convenience of electric drive is realized, it will only be a question of time until practically all of the small and medium sized stationary farm machinery will be driven by electric motors.

With rural electric development in its present stage, it appears that farm machinery requiring motors larger than five horse power capacity can be more satisfactorily driven by tractors. There are several problems of an engineering nature which enter into the use of large motors on farms, and until rural electric service becomes more standardized, farmers should not be too hasty in arranging to drive such machinery as ensilage cutters, threshing machines, and large sized feed-grinders with electric motors.

The following table gives the sizes of motors which it has been found most satisfactory to use for driving farm-power machinery and small household devices.*

*Taken from Circular 7179 of Westinghouse Electric and Manufacturing Company.

FARM MACHINES	HORSE POWER OF MOTORS USED FOR		
	Smallest	Largest	Usual Size
Bottle washers	1-8	3-4	1-2
Butter churns	1-8	3	1-4
Cider mills	2	5	2 1-2
Clover cutters	1-4	1-2	1-2
Concrete mixers	2	10	5
Corn shellers (single hole)	3-4	1 1-2	1
Cord wood saws	3	10	5
Cream separators	1-10	1-4	1-8
Ensilage cutters	10	25	15-20
Emery wheels	1-4	1	1-4
Fanning mills			1-4
Feed grinders small)	3	10	5
Feed grinders (large)	10	30	15
Forge blowers	1-15	1-8	1-10
Grain elevators	1-2	5	3
Grain grinders			1-4
Grindstones	1-8	1-4	1-4
Groomers (revolving)	1	2	1
Groomers (vacuum)	1	3	2
Hay balers	3	25	7 1-2
Hay hoists	3	15	5
Huskers	10	20	15
Lathes	1-4	1-2	1-2
Milking machines	3	5	5
Oat crushers	2	10	5
Refrigeration	1-2	25	3-5
Root cutters	1	5	2
Shellers (power)	10	15	15
Shredders	10	20	15
Threshers (19 in. cylinder)	12	18	15
Threshers (32 in. cylinder)	30	50	40
Vacuum system	2	3	3
Water pumps	1-2	5	3
Wood splitters	1	4	2
HOUSEHOLD MACHINES	HORSE POWER USED FOR		
Buffers	1-40	1-30	1-30
Dryers (Centrifugal)	1	2	1
Grinders	1-40	1-30	1-30
Ice cream freezers	1-8	1-4	1-8
Mangles	1-4	1	1-2
Meat grinders	1-4	3-4	1-4
Sausage stuffers	1-2	1	1-2
Sewing machines	1-40	1-30	1-30
Vacuum cleaners (portable)	1-83	1-45	1-83
Washing machines	1-8	2	1-8 - 1-4
Water pumps	1-4	1	1-2

In addition to the convenience, comfort and labor saving features of electricity on the farm, another very important reason why electricity should be used extensively on those farms where it is available, is that it will help to solve some of the problems which confront the central station operators in offering this class of service. If sufficient amount of current can be used to keep the individual transformers from operating on extremely light loads for several hours each day, it will improve the conditions under which the central station generating equipment must operate. This should not be taken to mean that electric power should be used when it is not necessary, merely to improve operating conditions, but the point is that if electricity from a central station or transmission line is going to be used at all, arrangements should be made to utilize it with profit as uniformly as possible throughout the working hours of the day.

In planning the use of electricity on a farm, its application for cooking and for minor heating devices should be given consideration. Electric ranges have been installed in many farm homes and the results in general are proving satisfactory. It has been found from experience that from .5 to 1 K. W. Hr.* per person per day is required for cooking for families of the average size. The following table gives the consumption of the various electric heating devices.*

HEATING DEVICE	POWER REQUIRED IN WATTS
Chafing dishes, 3 heat	150 - 600
Coffee perculators	380
Curling irons	15
Flatiron, 6 pound	550
Flatiron, 8 pound	635
Tailor's pressing iron	700 - 850
Nursery milk warmers	500
Radiators	500 - 3000
Ranges	1100 - 14000
Stoves, 6-inch, 3 heat	150 - 600
Toaster stoves	500
Toaster, vertical	500
Water heaters	700 - 10500

In planning the installation of an electric range, especially one of the larger sizes, it would be well to confer with the company from whom power is purchased. The effects of a limited number of ranges on the average farm line would probably not be noticed, but if the use of the ranges should become general among the customers on a rural line, the demand for power might exceed the central station supply at certain hours. Hence the advisability of conferring with the company furnishing power before a range is purchased. This precaution also applies to the installation of the larger sizes of motors.

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*Taken from 1920 Diary of Westinghouse Electric and Manufacturing Company.

HOW ELECTRICAL ENERGY IS CARRIED TO THE RURAL DISTRICTS

A fundamental rule governing the distribution of electrical energy is that it can be transmitted with a smaller loss at a high voltage than at a low voltage, other conditions being the same. It is not permissible to carry this high voltage into a residence, or about the farm on account of the hazards which it presents to life and property. Consequently, the electrical energy is transmitted from a central or sub-station at a high voltage and then changed to a low voltage by means of a transformer located at or near the farmer's premises. This transformer consists of two separate windings of copper wire, wound on a core built up of thin layers of annealed sheet steel. The coils and core are submerged in oil which is contained in a weatherproof case. One of these coils of copper wire is connected to the transmission line and the other to the circuits which carry the electricity to the places where it is used about the farm. There is no connection whatever between these two coils of the transformer so there is no danger of the high voltage being carried into the house, unless the transformer becomes defective, and this is a very rare occurrence. If adequate protective devices are properly installed at the transformer, there is very little danger of damage from lightning, for the exposed part of the transmission line terminates at the transformer.

PLANS FOLLOWED IN SERVING RURAL DISTRICTS

Three general plans are being used in Iowa in supplying electric service to rural consumers. These are:

1. Where the farmers as a group, build, own and maintain the line and buy power on a wholesale basis.

2. Where the farmers as a group, build the line, but as soon as it is completed and ready for service, the ownership of the line passes to the power company as compensation for maintaining the line in good, serviceable condition for a stated period of time, say twenty years.

3. Where the power company build the line, supply transformers and deal with the rural customers in much the same way as with city customers, except a higher rate is charged to the former than to the latter.

There are doubtless instances where other methods are in use for supplying rural service, for example a few farmers are being served directly from transmission lines that have been built to serve small towns, but in most of these cases one of the methods mentioned above, or a modification of one of them, is the basis of the contract that is in use. Each of the methods that has been briefly described has advantages and disadvantages that merit consideration and each is advocated by certain experienced central station operators. The plan which is best to use is not a question to be decided solely by the group of farmers concerned, nor by the central station which is selling the power, but should be decided upon through a mutual agreement between those who are to use the power and those who have it to sell.

In the case where the farmers build their line and retain ownership in it, an objection which is frequently raised, is that the farmer is not informed regarding the maintenance of lines of this character. This objection is well founded and no one realizes it more than the farmer himself. However, this difficulty is usually overcome by having an agreement with the power company whereby their employees will be loaned to the farmers' organization to make needed repairs. The cost of labor and material incurred in making these repairs is then billed to the farmers in the customary way and the proper official of the farmers' organization pays the charges. It should be realized that the successful operation of rural lines and the continuity of service which will be obtained from them, depends on prompt and adequate maintenance. This means that the lines should be patrolled frequently, and any needed repairs reported promptly to those who are responsible for the maintenance. This will add to the efficiency of the line and prevent many interruptions of service. In localities where there are several rural lines, it may be possible to engage the services of a competent electrician who will devote all of his time to patrolling, inspection and minor repair work. The expense of such service could be borne equally by the various farmers' organizations and this doubtless would be the most economical way to insure the lines being properly patrolled and maintained.

HOW TO PROCEED TO OBTAIN RURAL SERVICE

The first step which should be taken in the promotion of a rural electric line is to find out approximately what the line and service are going to cost and under what conditions the power company prefer to sell the current. With a statement to this effect endorsed by responsible persons, a canvass should be made of the locality to be served, for the purpose of securing the names of all those who are willing to receive the service and support the project. If a sufficient number of signatures are secured to justify further action, a meeting should be called and an organization formed.

The method of procedure from this point on, depends upon which of the three plans mentioned above is to form the basis of the contract for current. If a group of farmers is to retain ownership in the line and be responsible for its maintenance, there are two methods that are being followed. One of these is to place all matters relating to organization, construction and contracts in the hands of a promoter. The other is where the farmers handle these matters among themselves as an organized group. Both methods have brought satisfactory results where the management has been in the hands of competent and responsible persons.

When a promoter is in charge, the farmers are relieved of many burdensome details incident to a project of this sort, and their only concern should be to assure themselves that the promoter is a responsible party, and that he is following competent legal and engineering advice. When the farmers are handling the matter themselves, their organization should appoint a committee with authority to transact all business necessary to construct lines and contract for power. It is just as important that this committee follow good legal and engineering advice as it is for a promoter to do so and the organization should insist that this be done.

Where the ownership of the line is to pass into the hands of the power company when service is started, the methods of procedure described above may be followed with respect to organizing and building the line. However, the power company will probably manifest an interest in the type of construction that is used since it will be responsible for the maintenance after ownership passes into its hands. There may be instances where farmers will wish to assist in the construction of their lines to reduce the expense of building. Provided arrangements can be made with the contractor who is building the line, there is no reason why this should not be done to the extent of hauling material, digging the holes and assisting in raising and setting the poles. All line work, however, including the mounting of lightning arrestors, hanging of transformers and making service taps should be performed by experienced linemen.

When the power company builds the lines and deals with rural customers individualy, there is very little for the farmer to do except arrange to have his house and premises wired so that he may be given service as soon as the line is ready.

Regardless of the plan followed in giving rural service, a franchise must be obtained before a transmission line may be constructed. This franchise can be obtained either thru the Board of Railroad Commissioners at Des Moines, or thru the Board of Supervisors of the county where the line is to be built. While either of these bodies may legally grant a franchise, the Railroad Commission employes an electrical engineer whose duty it is to approve material and construction specifications and the route to be followed before the franchise is granted. The Supervisors on the other hand do not usually have access to an engineer's advice and for this reason some of the important matters which should be taken care of before a franchise is granted, are likely to be overlooked.

Since there are many problems involved in the planning and building of rural transmission lines, each organization should employ a competent engineer to represent it in all matters of an engineering nature. The cost of such service is small when compared with the total cost of the line and there are many ways in which an engineer's fees may be more than saved if his advice is followed.

LINE MATERIAL SPECIFICATIONS

These specifications cover the material that should be used in building rural service lines of from 2300 to 6600 volts, single or three phase. Their arrangement is not suitable for use in calling for bids, but their purpose is to serve as a guide for those who may wish to determine if materials of the proper quality are being used in the construction of rural transmission lines. Where dimensions are given they should be considered as being minimum, rather than maximum, requirements to insure safety.

POLES: All rural service lines should be built on good sound cedar poles (Northern or Western), and should conform to the Northern or Western Cedar specifications covering the respective sizes.

In view of the general shortage of poles for the season of 1920, those who are having lines built should exercise extreme care to see that only first class poles of the sizes specified are used. A cheap grade of poles means inferior construction, increased maintenance charges and a short life of the line. The cost of poles has increased materially during the last few months. This makes it all the more necessary to set only butt-treated poles in order that the life of the line may be increased as much as possible. While butt-treatment by the brush method is worth while, tank-treated poles are much better and are easily worth the increase in cost. It would be well to specify that all poles for rural transmission lines in Iowa be given "open tank" treatment, specification "AA". This will insure a well treated pole and one whose average life will be increased at least fifty per cent.

The material desired under the specifications for NORTHERN WHITE CEDAR poles consists of the best quality of either seasoned or live green cedar of the dimensions hereinafter specified. Seasoned poles shall have preference over green poles provided they have not been held for seasoning long enough to have developed timber defects. All poles shall be reasonably straight, well proportioned from butt to top, shall have both ends squared, the bark peeled and all knots and limbs closely trimmed.

POLE DIMENSIONS: No poles should be used in building rural transmission lines whose length is less than twenty-five feet and whose top diameter is less than six inches. For the number of poles which should be used per mile, refer to paragraph on "SPANS", page 11.

The dimensions of the poles shall be in accordance with the following table, the "top" measurement being the circumference at the top of the pole and "butt" measurement the circumference six feet from the butt.

	CLASSES					
	A		B		C	
	Circum. in inches		Circum. in inches		Circum. in inches	
Length of poles in feet	Top	6 ft. from Butt	Top	6 ft. from Butt	Top	6 ft. from Butt
25	24	36	22	32	18¾	30
30	24	40	22	36	18¾	33
35	24	43	22	38	18¾	36
40	24	47	22	43	18¾	40
45	24	50	22	47	18¾	43
50	24	53	22	50	18¾	46

The material desired under the specifications for WESTERN RED CEDAR poles consists of poles and guy stubs of the best quality of either seasoned or live green cedar of the dimensions hereinafter specified. The poles covered by these specifications are of Western white cedar, otherwise known as red cedar, or Idaho cedar. Season poles shall have preference over green poles provided they have not been held for seasoning long enough to have developed timber defects. All poles shall be reasonably straight, well proportioned from butt to top, shall have both ends squared, sound tops, the bark peeled, and all knots and limbs closely trimmed.

The dimensions of the poles shall be in accordance with the following table, the "top" measurement being the circumference at the top of the pole and the "butt" measurement the circumference six feet from the butt. The dimensions given are the minimum allowable circumferences at the point specified for measurement and are not intended to preclude the acceptance of poles of larger dimensions.

When the dimension at the butt is not given, the poles shall be reasonably well proportioned thruout their entire length. No pole shall be over six inches longer or three inches shorter than the length specified. If any pole is any more than six inches longer than required, it shall be cut back.

	CLASSES					
	A		B		C	
	Circum. in inches		Circum. in inches		Circum. in inches	
Length of poles in feet	Top	6 ft. from Butt	Top	6 ft. from Butt	Top	6 ft. from Butt
25	28	34	25	31	22	28
30	28	37	25	34	22	30
35	28	40	25	36	22	32
40	28	43	25	38	22	34
45	28	45	25	40	22	36
50	28	47	25	42	22	38

CROSS ARMS: Cross arms should be of fir or long leaf yellow pine. They should be made of straight grained wood which has been properly seasoned, and which is practically free from timber defects. Clear and unpainted cross arms may be used. Dimensions should conform with the following table:

Type Cross Arms	Length	Thickness and Width	Size of Pin Holes
Elecrtic Light			
2-pin	36 in.	3¼x4¼ in.	1½ in.
4-pin	48 in.	3¼x4¼ in.	1½ in.
N. E. L. A.			
2-pin	38 in.	3½x4½ in.	1½ in.
4-pin	67 in.	3½x4½ in.	1½ in.

Cross arms must be secured to the poles by means of thru bolts, and braced with two braces fastened to the cross arm by means of carriage bolts 3/8x4", and to the poles by means of a 1/2x3" lag screw. No lag screws shall be used to fasten cross arms to poles.

CROSS ARM PINS: Cross arm pins should be locust or an approved type of metal pin. If wooden pins are used they should not be smaller than 1½ inches in diameter by 9 inches in length.

HARDWARE: All hardware should be galvanized in accordance with the specifications of the National Electric Light Association.

PIN INSULATORS: Porcelain insulators only shall be used on all voltages up to and including the maximum voltages covered by these specifications.

Line voltage	2,300 to 6,000 volts
Dry arc over voltage	45,000 volts
Wet arc over voltage	25,000 volts
Leakage distance	4 inches
Mechanical strength	5,000 pounds

STRAIN INSULATORS:

Line voltage	4,000 volts
Wet arc over voltage	15,000 volts
Mechanical strength	12,000 pounds

LINE CONDUCTORS: The wire used in rural service lines should be "hard drawn" or "medium hard drawn" bare copper or steel reinforced alumnium cable. On account of the necessity of making the lines safe and strong, nothing smaller than No. 6 B and S. gauge or its equivalent should be used. A few lines have been built recently using stranded bare copper wire which has the advantage of being easier to handle and less susceptible to mechanical injury than solid wire. There is a possibility that the splices in stranded wire may develop a high resistance due to corrosion. None of these lines have been up long enough to verify this from experience.

Aluminum has the advantage of being lighter, and on account of the high tensile strength of the steel core, is stronger than its equivalent size in hard drawn or medium hard drawn copper. This increase in strength makes it possible to pull the wire tighter, which permits the poles to be spaced farther apart while maintaining sufficient sag and clearance. On account of the difference in tensile strength of the steel core and the aluminum strands which surround it, a special device is necessary at all places where steel reinforced aluminum strand conductors "dead end", and specially designed clamps should be used instead of soldered joints in making service taps from the transmission line. There are several transmission lines using aluminum conductors in Iowa which are giving satisfactory service but so far its use for rural lines has not become general. Under the present market conditions aluminum is somewhat cheaper than copper.

LINE CONSTRUCTION SPECIFICATIONS

These specifications, like those for line material, are intended to serve as a guide so that those who are not familiar with construction methods may know when their lines are being properly built.

POLES: Poles supporting rural service circuits should be set in accordance with the following table:

Length of poles in feet	Depth in ft. in earth	Depth in feet in rock
25	4.5	3.0
30	5.0	3.5
35	5.5	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.5	5.0
60	8.0	5.0

When located in soft or swampy ground, the setting of the poles shall be suitably reinforced. This may be done by setting in barrels of broken stone or gravel, or in stone or timber footings, or by other equally effective methods.

Since it may be necessary to convert some single-phase lines into three-phase lines in order to provide for increase in line capacity, it may prove economical to build the original line so that an additional wire may be strung without making any changes in the existing line. This feature should be taken into consideration when specifying poles and cross arms for the line when it is first built.

SPANS: The spacing for poles for rural transmission lines depends upon the size of poles, the kind of material used for line conductors and somewhat upon the topography of the country over which the line is built. If 25-foot poles are used, no span should exceed 130 feet, but this may be increased to a distance not to exceed 150 feet if 30-foot poles are set. In case steel reinforced aluminum line conductors are used, both of the above distances may be increased to 150 and 175 feet respectively.

GUYING: Wood poles supporting the crossing span should be side guyed in both directions if practicable and right of way conditions permit and be head guyed away from the crossing span. The next adjoining poles should be head guyed in both directions if practicable. Braces or push guys may be used.

Strain insulators should be used in all guys attached to poles supporting circuits having a voltage as high as 6600 volts.

At all points of unbalanced strain, the line should be securely and properly guyed. Guy wire should not be less than 1/4" seven strand galvanized steel strand. No single wire guy material should be used.

ANCHORING: Anchors should, if soil is wet, boggy or sandy, and if of such character that patent anchors will not hold, be of the log type. Approved patent anchors may be used in firm and solid soils. Anchor rods should not be less than 5-8 inch diameter, galvanized, and not less than six feet long.

HANDLING WIRE: Great care should be exercised in handling the wire that is to be used in transmission lines. A small nick or scratch made in hard drawn solid copper wire is likely to result in a break within a few months after the wire has been strung and subjected to tension. In securing the line wire to insulators, nothing but annealed copper tie wires of the same size as the line wire should be used. If these tie wires are "cinched" too tight, the line wire will be "burned" at this point and a break in the line is almost certain to follow. All splices in line wires should be made with copper sleeves or an approved type of twist joint and care should be taken not to exceed the number of turns necessary for making a splice with the size of wire that is being used. An approved type of twist splice such as a "three wire splice" may be used in the case of a solid conductor. If care is taken, this splice can be made up and sufficiently soldered without reducing the strength of the joint or increasing the resistance.

LIGHTNING ARRESTORS: An approved type of lightning protection consisting of a grounding device and fuse cut-outs should be installed in each wire on the high voltage side of each distributing transformer. Suitable protection should also be installed at sub-station transformers which supply power to rural transmission lines. Some central station operators object to the use of horn-gap lighting arrestors, giving as their reason that such arrestors have a tendency to cause surges on the transmission line which result in troublesome line disturbances.

GROUNDING: The neutral wire in the case of a three-wire secondary, or one of the wires in the case of a two-wire secondary should be "grounded" at each distributing transformer. Ground connections for lightning arrestors and distributing transformer secondaries should be made by using an insulated copper wire not smaller than No. 6 B. & S. gauge, soldered to a galvanized ground pipe or galvanized ground rod not smaller than 5-8″x6 feet. Lightning arrestor ground and transformer secondary ground ought not to be connected to the same ground pipe or rod.

TRANSPOSITIONS: All farm lines carrying a voltage of 2,500 or over, should be transposed once every mile. This should be done by placing an additional cross arm 24 inches below the top arm, and bringing the left hand wire down on to the lower arm and out on the right hand side of the next pole, thereby interchanging pin positions. If the line is three-phase, the same general scheme of transposition should be followed. In some cases it may be necessary to make transpositions which will co-ordinate with those of parallel metallic telephone lines.

RIGHTS OF WAY: Suitable right of way for rural service line should be secured and should be subject to inspection and approval of the owners of transmission line, and others whose duty it may be to patrol the line.

DANGER SIGNS: Danger signs should be placed on poles of all transmission lines in accordance with the requirements set forth in Chapter 174, 35th General Assembly, Section 2120-r (Supplement of Code of 1913).

JOINT CONSTRUCTION: A number of instances have arisen where joint construction between telephone and power lines seemed desirable. This is a bad condition with which to contend and should be avoided if it is at all possible to do so. Such construction causes an increased hazard to telephone lines when the two kinds of circuits are placed on the same set of poles, and every effort should be made to place the telephone and transmission lines on *opposite* sides of the highway. For additional discussion on this point, see page 22.

SELECTION OF VOLTAGE FOR RURAL LINES

Several different voltages are being used for supplying rural service, but 2,300, 4,400, and 6,600 are looked upon with the most favor at the present time. In some cases, farmers are being served directly from transmission lines of a higher voltage which run between towns, but this practice is not general. There are also a few instances where farms located close to the city limits are reached with extensions from city lines that carry a voltage less than 2,300, but these lines are short and cannot be extended far into the country unless changed to a higher voltage.

The experience gained in the past two or three years indicates that rural service should be given from lines built especially to serve rural customers. It is objectionable to tap onto high voltage trunk lines running between towns because transformers and protective devices adaptable to such voltages are more expensive, and also conditions may develop at any one of these taps which will put the line out of order and cause interruptions in the service for an entire community. The objection to using a voltage less than 2,300 is that the lines are limited in length to two or three miles and no extensions can be made and have good service without using very large wire, and this usually is prohibitive from the standpoint of cost.

The selection between 2,300, 4,400 and 6,600 volts for a rural transmission line depends upon the number of farmers which are to be served, the amount of power which each expects to use and the ultimate length of the line. With the customary loading of from two to four farms per mile, a 2,300 volt line should not exceed six or seven miles in length, assuming that the line is built of No. 6 B. & S. gauge copper. If there is a possibility that the line will be longer than this, 6,600 volts should be adopted. The "length" in this case, does not refer to the total miles of line necessary to reach all the customers, but to the distance from where the line starts, out to the customer living farthest away.

The reason for recommending 6,600 volts is that the per cent of line loss to power transmitted is less, the line will serve a larger load and it can be built farther in the country and yet maintain the proper voltage, than is the case with either 2,300 or 4,400 volts. There may be some cases where the use of either of these voltages may be advisable, but unless there is some special reason for using one of them, 6,600 volts will prove to be more satisfactory.

It is impractical to plan on starting with a voltage of 2,300 and later changing to a higher voltage if there is a demand for service which will make it necessary to extend the line. This would mean that the transformers all along the line would have to be changed, the arrestors would very likely need to be replaced and, unless such a procedure had been anticipated, it might be necessary to change the insulators.

In many instances, 2,300 volts may be as high as is available without the installation of a step-up transformer. Such a situation would indicate that the use of this voltage would be preferable. However, before a decision is made, the matter should be gone over carefully to make sure that the saving effected in not installing a step-up transformer is worth the chances that are being taken in not having to make expensive changes later to extend the line. If it seems advisable in any case to use 2,300 volts, the line should be built so that it could be changed from single-phase to three-phase distribution to provide additional capacity if more is needed. This would not be impractical nor should it be expensive.

There is very little choice between 2,300, 4,400 or 6,600 volt lines with respect to danger from fire or hazards to life. All are extremely dangerous from the standpoint of touching, or coming in contact with the wires carrying these voltages, or with any metallic substance which does touch them.

The lower voltages have a slight advantage in the cost of insulators, transformers, and protective apparatus. This difference in cost, however, does not amount to a great deal and is small when compared with the improved service conditions which one is assured of having if 6,600 volts are used.

TRANSFORMERS

It is necessary to install a transformer at or near the premises which is to be supplied with electricity. The purpose of this transformer is to reduce the voltage from that of the transmission line to one which will be safe to carry into the house and about the farm wherever light and power is desired. The transformer which is to serve a farm should be located as near as possible to the point where the heaviest current will be used. It is generally located on the line pole which stands nearest to the residence but frequently is suspended from a pole located in the yard or elsewhere about the place. One thing which should be kept in mind is that long runs of wire from the transformer to any of the consuming devices, especially motors should be avoided. The question is often raised, relative to one transformer serving two customers. This is permissible if the customers live close together. But it is safe to put a limiting distance of 300 feet as a maximum which current should be carried from transformer to lights, small motors and household appliances, and 100 feet to power motors and stoves.

The proper size of transformer to install is a question which should be given careful consideration. If only lights, household appliances and small motors are used, the transformer should not be larger than 1 K. V. A. if connected to a 2,300 volt line, or 1½ K. V. A. if connected to a 6,600 volt line; 1½ K. V. A. being the smallest standard size transformer for 6,600 volts. If motors larger than 1 H. P. are used or if current is used for cooking, a larger transformer may be necessary; the size depending on the rating of the motors and the capacity of the electric range.

The reason that it is important to use a transformer which bears the proper relation to the connected load, is that transformers operate at very low efficiency when lightly loaded, and it is therefore desirable that a size be used which will avoid this condition. Another reason for using a transformer of the proper size is that there are certain losses that occur while the transformer is connected to the transmission line, regardless of whether any current is being used from the transformer or not. These losses are known as "iron" or "core" losses and they consume real electrical energy just as much as lamps, flat-irons, motors or any other electrical appliances. To illustrate what these losses amount to, we will take a 1 K. V. A. transformer and see what it costs per month to satisfy these losses.

The core loss for a 1 K. V. A. (2,300 volt, 60 cycle) transformer is approximately 20 watts.

20x24x30=14400 watt hrs.=14.4 K. W. H.

14.4 K. W. H. at 10 cents =$1.44 per month.

If the transformer is 2 K. V. A. these losses amount to $1.80 per month and for a 3 K. V. A., $2.30 per month. As mentioned before these losses are independent of the load being taken from the transformer. So if only a small amount of power is to be used, a small transformer should be installed. Another disadvantage in using larger transformers than are necessary, is that when a large group of lightly loaded transformers are connected to a distributing system, a very low "power-factor" results. This means that a heavier current must be generated and sent out over the line than should be necessary to get the required power out to the consumers. Such conditions reflect back to the generating equipment in the central station and make it difficult to render first class service. In the case of a large system and a few lightly loaded transformers, the conditions just mentioned would be negligible, but there will doubtless be many instances where large groups of farmers will be served from small central and sub-stations and unless this feature is guarded against, operating conditions may become so bad that it will be impossible to give good service.

In trying to decide the proper size of transformer to install, it will be of interest to know that when most transformers are operated at half load or over, their efficiency is comparatively high and that they may be heavily overloaded for a few minutes without being damaged. A transformer such as should be used for rural service will stand a 25% overload for two hours or a 50% overload for thirty minutes with safety.

To illustrate how much power can be obtained from 1 K. V. A. transformer, we may assume that the type of motor which will be utilized for light farm work to have a power-factor of .8 and an efficiency of .85. Since 746 watts equal one horse power.

$$\frac{746}{.8 \text{x} .85} = 1097 \text{ watts.}$$

One K. V. A. = 1,000 watts, and if it is 50% overloaded, 1,500 watts could be taken from it.

$$\frac{1500}{1097} = 1.4 \text{ H.P. approximately.}$$

If only a motor load is taken from the transformer, a 1 H.P. motor could be operated continuously or a 1½ H.P. motor could be run for thirty minutes. When the motor was not in use, the 1 K. V. A. transformer would easily provide current for all lights, and the ordinary household appliances, flat-irons and washing machines included, that are likely to be used at any one time. This size transformer would also supply current for the smaller sizes of electric ranges for cooking. The above discussion is based on the assumption that the rural transmission line has a voltage of 2,300. If the line was operating on 6,600 volts, the smallest size standard transformer would be 1½ K. V. A. This would permit the continuous use of a 2 H. P. motor, or a medium sized range and all of the other heating and small motor appliances which the ordinary farm home would find it necessary to use.

From what has just been said, it is evident that the amount of electric current which can be obtained for farm power purposes is limited, if the size of the transformer is kept down to a minimum in order to improve the operating conditions of the line. While this is contrary to the ideas held by many, it is nevertheless the case and some other means must be provided for those rural customers who will need electric power to drive some of the heavier farm power machinery.

The plan which seems most practical under the present conditions is to have two transformers, one small one to serve for lighting, cooking appliances and small motors, and one larger one equipped with some convenient form of disconnecting switch which may be safely operated from the ground. This larger transformer could be wired directly to the power motors and when it is desired to use them, the switch could be closed and then opened when the power for these motors is no longer needed. The switch for this transformer should be so arranged that when open it would disconnect the transformer from the transmission line thus eliminating the core loss when the transformer was not in use as well as the bad condition of having an idle or lightly loaded transformer connected to the transmission line.

Another plan which has been suggested, but which has had very little if any application is to install motors for driving power-machinery which will operate directly from the transmission line. This will eliminate the use of the larger transformer and disconnecting switch mentioned above, but it would necessitate a permanent installation in an enclosed motor house which would be so located that the various power machinery to be driven could be moved up to the motor as it was needed. An installation of this sort can be employed only on a 2,300 volt, three-phase system as single-phase motors are not built to operate on voltages this high. Such an installation is open to the objection of having to carry high voltage circuits on to the premises of the customer and of requiring a three-phase distributing system built out into the rural districts. While these conditions are acceptable in many industrial installations, it is very doubtful if such a practice would be approved in rural electric line construction in its present stage of development.

METERING ON FARM LINES

The proper method of metering on rural electric lines depends upon the plans under which the service is being rendered, and the rates that are charged for electric energy. So closely is the method of metering related to rates that the two should nearly always be considered together.

When current is purchased on the wholesale basis, a meter should be installed at the point where the rural line receives its power. If a transformer is necessary at this place, the current may be metered on either side, but the side where the meter is located should be specified in the contract. For when it is connected on one side, it will record the core loss of this transformer, while if it is located on the other side this loss will not be indicated. Since this transformer is usually a large one, and is on the line continuously, this is an appreciable item. The cost for metering equipment to operate on the high voltage side is greater than on the low voltage side, and since the core loss of a transformer which is continuously connected to the line is constant at all loads, and can be closely approximated, it is better to meter on the low voltage side unless there is some special reason for doing otherwise. The meter which is located at this point is usually called the "master meter."

In all cases a meter known as a "service meter" should be installed on every customer's premises. This should be located in an easily accessible place and where it will not be subject to the weather, vibration or to undue chances for mechanical injury. A very convenient and satisfactory way to install a service meter is to mount it in a weather and fire-proof box which should also include the service switch and fuses. This box can be mounted on a back porch or basement and the wiring necessary to connect up the meter simplified.

It has been advocated by some that in cases where the rural service line is not owned by farmers, the meter could be located on the transformer pole and the metering done on the transmission line side of the individual transformer, thereby measuring the energy that is necessary to overcome the core loss of the transformer. This is not satisfactory nor practical for the reason that the current on the high voltage side of the transformer necessary to meet the core loss only, is very small, and is not enough to cause the moving element of the meter which drives the recording mechanism, to rotate.

It frequently happens that electrical energy is sold to the same customer at two different rates, for example, one rate may apply to light and small household appliances and the other to cooking or power, or perhaps both. In such cases a separate meter will be required for each rate so that the amount of current used for the different purposes will be recorded separately and the customer may be billed accordingly.

As a rule the average customer, both city or rural, knows very little about the operation of the electric meter. There is no reason why every customer should not know how to read a meter correctly and thus check up his bills as they are rendered. The modern meter reads directly in kilo-watt hours and consists of four small dials each of which is traversed by one hand. The hands of adjacent dials rotate in opposite directions and one complete revolution of a dial hand is indicated by one division on the first dial to the left. To get the correct reading at any time it is only necessary to set down the number on each dial which the hand has just passed, keeping in mind that the number read from the right hand dial represents units, the one taken from the second dial from the right represents tens, etc.

A very common complaint on the part of the customers is that the meter does not measure their current correctly or that their meter is running fast. Occasionally a meter does get out of adjustment but it has been proven many times that the per cent of meters which record incorrectly is very small compared with the number of complaints. It should be remembered, of course, that while service meters are commercially accurate, it is impossible to make them on a commercial basis so that they are mechanically perfect. For this reason an allowance is always made which will permit a meter to vary four per cent, that is, its accuracy may vary from two per cent slow to two per cent fast. So long as its registration falls within these limits, no adjustments are considered necessary.

In case any customer feels reasonably certain that his meter is not registering correctly, he should ask the company from whom the electric power is being purchased, to check the meter with a standard instrument. This is a very simple matter and most central stations are equipped with adequate checking instruments with which this test can be made.

HOUSE WIRING

Since electric wiring is a class of work which is frequently done in an unworkmanlike manner, the wiring for the house and all other farm buildings should be placed in the hands of a competent electrician. It is also desirable to have the contract covering all inside wiring jobs specify that the rules of the National Electric Code be followed. This Code is a set of rules covering all classes of inside wiring and has been approved by the various electrical organizations and fire insurance companies in the United States. With the exception of some cities where these rules are not considered rigid enough to cover special conditions, they are accepted as a standard in all parts of the country. Every farmer having wiring done should insist that the rules of the National Electric Code be followed in all cases where they apply to the work being done.

There will doubtless be some cases where houses have been wired for thirty-two volt farm lighting plants that will be connected to a rural transmission line. If the wiring was properly installed originally, there is no necessity of making any changes, although it would be advisable to have an inspection made by a competent electrician for the purpose of discovering any defects which may exist.

The cost of electric wiring will vary in different localities and with the different classes of work to be done. Charges are usually made on an outlet basis, which means that a certain amount is charged for every place that two wires are brought out for connecting in a switch, receptacle or a fixture. These prices may or may not include all but the lamp, according to the method the electrician doing the work prefers to follow. The prices will vary in the wiring of finished buildings, on account of the different types of building construction. In houses having single floors, the charges will probably vary from $2.50 to $3.75 per outlet, while in houses having double floors, the price will be somewhat higher. The reason that the kind of floors affects the price is, that pieces of the flooring will need to be removed to install the wires, and the more difficult it is to take these boards up and put them back, the higher will be the price charged for wiring.

For the wiring of the various farm buildings such as barns, sheds, garages, etc., where the wiring need not be concealed, it would be a difficult matter to state anything like a uniform price on the outlet basis. In such installations one switch may control several lights and the runs may be long, requiring a great deal of wire, so that this method of charging would need to be worked out for each building. A more satisfactory way to do this class of wiring would be on a time and material basis, then it could be done just as the owner wants it, regardless of the amount of material necessary.

One feature to be kept in mind in connection with the wiring of a house or any building where lights, appliances and small motors are to be used, is that provisions should be made for a sufficient number of outlets so that it will not be necessary to do temporary wiring later. This especially applies to barns and other similar farm building where dust and cobwebs, which are inflammable, are likely to collect. Many of the fires due to defective wiring can be traced to conditions of this sort and no wiring should be permitted which has not been installed by a competent electrician. Another point which should be emphasized is that every person who has electric lights will need a safe and serviceable extension cord. This is a piece of lamp cord, preferably with "reinforced" insulation, one end of which is connected to an attachment plug for screwing or pushing into a receptacle or socket, and the other end to a lamp socket provided with a lamp guard. This makes it possible to have a safe portable light which is often necessary in doing certain kinds of work requiring a lamp placed so as to produce intense illumination.

LAMPS AND FIXTURES

The right selection of lamps and fixtures should be made if the correct amount of illumination is obtained for the various rooms of the house. The principle factors which determine the amount of light necessary to give sufficient illumination are, the size of the room, the color of the walls and ceiling and the purpose for which the light is used. Light colors and smooth wall finishes reflect more light than others and therefore it is necessary to take this into account in selecting the lamps and fixtures. There is some difference in the light producing characteristics and efficiency of the various types of incandescent electric lamps that are in common use.

The carbon lamp is perhaps the most rugged of any, but it also has the lowest efficiency. Its ability to withstand handling and vibration make it adaptable to rough portable use where a good quality and high efficiency in illumination are not important.

The Mazda B lamp is used extensively for general illuminating purposes. It has fairly high efficiency and is made in a variety of sizes suitable for household lighting. Its filament is rugged enough to withstand some handling, but it is not uncommon for this type of lamp to have a very short life when subjected to service which requires that it be changed frequently from one socket to another. This lamp has a comparatively long filament, which, when lighted is not heated to as high temperature as is the case in some of the other lamps. For these reasons it does not produce objectionable glare. The Mazda B lamp varies in size from 10 to 100 watts. It may be burned in any position and its average life is 1000 hours.

The Mazda C lamp is what is known as a nitrogen or gas filled lamp. That is, instead of the bulb being a vacuum, it is filled with an inert gas which makes it possible to heat the filament to a much higher temperature without undergoing rapid deterioration. This lamp has a high efficiency and gives intensive illumination, but on account of its short filament which is heated to a high temperature, it causes objectionable glare when placed in the field of vision. Its illumination is of better quality than that of the Mazda B, but it is less rugged and should be handled as little as possible. In sizes it ranges from 75 to 1000 watts. The 75, 100, and 150 watt sizes may be mounted in any position but the larger sizes should be burned only with the tips down. Its average life is 1000 hours.

The Mazda C-2 is very similar to the Mazda C, but its globe is blown from a blue colored glass which results in a quality of illumination being given off that more nearly approaches sun light than that of any other type of electric lamp. This makes its use especially desirable in places where it is necessary to determine true colors under artificial lighting conditions. When placed directly in the field of vision, it produces a peculiar sensation to the eyes but when properly protected it is an excellent lamp for reading purposes. It has a lower efficiency than the Mazda C is made in sizes ranging from 75 to 500 watts and has an average life of about 700 hours. The 75, 100, and 150 watt sizes may be mounted in any position but the larger sizes should be burned with the tips down.

The White Mazda is the latest development in the way of incandescent electric lamps to be placed on the market. This is also a gas filled lamp and its shape is similar to that of the Mazda C and C-2. Its globe, however, is blown from a white glass which diffuses the light and practically eliminates the glare. In efficiency it lies between the Mazda C and C-2. It is made only in a 50 watt size, has about the same amount of ruggedness as the Mazda B and may be burned in any position.

The voltage rating of each of the lamps described above is from 110 to 125 volts, and to get the best results, the voltage of the circuit at the lamp socket should fall within this range.

The successful lighting of the home does not depend entirely upon the kind and size of lamp used. After the light has been provided, it is than necessary to use some kind of a shade or reflector to direct the light to those parts of the room where it is needed.

The kind and type of fixture that should be installed depends upon the purpose for which the light is to be used, the dimensions of the room and how the room is decorated.

A great deal more might be written on this subject but it is treated more fully in other publications that are available for distribution to those who wish to select efficient lighting layouts that will harmonize with their local conditions.

INTERFERENCE WITH TELEPHONE LINES

There are two ways in which rural transmission lines may interfere with telephone lines. One of these is where a physical contact may be made between the two circuits and which exposes the users of the telephone line to a very dangerous condition. The other is where the transmission line, if built too close to the telephone line, will cause the telephone circuit to become noisy and may prevent any service from being received over it. This noise is usually spoken of as "inductive interference", and is more difficult to avoid on grounded telephone lines than on metallic lines.

In planning to build a rural transmission line, a route should be selected which will avoid unnecesary paralleling and crossing telephone lines. The objection to crossings is that the wire which is above may break and fall, so that it comes in contact with the other circuit, thus producing a dangerous condition. One point of contact will energize an entire telephone line, subjecting all of the subscribers on the line to a hazardous condition. This hazard may be reduced so that there is very little danger of serious shock by installing an arrestor having heat coils and spark-gaps at each farm telephone. In case of a cross between a telephone line and transmission line, the heat coil would automatically disconnect the telephone from its line and the spark-gap would place a positive "ground" on the transmission line, making it much less dangerous. This latter feature would, however, be of very little value unless the ground connection of the arrestor was made in an approved manner. This consists principally in installing the ground rod in such a way that it extends into moist earth at all seasons of the year.

Inductive interference is only produced when a transmission line parallels a telephone line. The amount of interference depends on several conditions, the more important ones from a rural transmission line standpoint being, length of parallel, distance between lines, voltage of the transmission line, and whether the telephone line is metallic or grounded.

In order to reduce interference of transmission lines with telephone lines to a minimum, the following precautions should be taken:

1. Avoid all unnecessary crossings. This includes where the transmission line crosses the telephone drop wires leading from the line into a house.

2. Avoid the unnecessary building of transmission lines on the same highway with grounded telephone lines.

3. Avoid building transmission line on same side of highway, with any telephone lines.

4. If a transmission line is built on the highway with telephone lines, proper transpositions should be placed in both transmission and metallic telephone circuits.

5. Where transmission and telephone lines follow the same highway, both should be well maintained and kept free from "grounds."

6. Where transmission lines and telephone lines have different owners, they should co-operate with each other in solving the interference problems.

7. Before building a transmission line which may produce interference, secure engineering advice.

Rules for construction involving the crossing of telephone and telegraph lines by transmission lines are contained in a bulletin issued December 30th, 1916, by the Board of Railroad Commissioners, Des Moines, Iowa. These rules should be followed in all cases where they apply.

FACTORS INVOLVED IN THE COST OF RURAL SERVICE.

The method of determining the proper rate for electrical energy is in general no different from the method followed in determining the price per bushel at which a crop of grain must be sold in order to make the production of that crop a profitable enterprise. Omitting the details in each case, it becomes a matter of balancing the revenue obtained

against the actual cost of production. And in this cost of production should be included the right proportion of fixed charges on the equipment used, overhead expense and operating costs necessary to produce the product under consideration.

An analysis of the cost to produce and distribute electrical energy to the point where it is sold, shows that there are two distinct parts to this cost. Briefly described, these parts are as follows:

1. A fixed cost which is independent of the amount of power used. In other words, a cost which is practically the same whether the plant operates at light load or full load.

2. A variable cost which depends on the power generated.

The first part includes such items as interest on capital invested in equipment, depreciation of physical plant, overhead expense, taxes and insurance. It is obvious that each of these items represents a definite expense that must be met out of the revenue obtained from the product sold. This set of items, however, contains one which is often a source of disagreement, and that is the valuation of the plant, or the actual amount of capital which the plant represents. The importance of having the correct amount for this item is easily appreciated. If the valuation is too high, the interest on the invested capital will amount to more than it should, thus making the rates higher than they ought to be. If the valuation is too low, a sufficient amount of the income will not be set aside to cover the interest on the true amount of capital invested, which means that if all the other items have been properly determined, the company will operate at a loss.

The item of depreciation means that a certain amount of the income must be set aside each year to compensate for the unavoidable deterioration of the physical plant. This does not include maintenance expense, for regardless of how well a piece of machinery is maintained, that machinery will in time wear out. If, however, the matter of depreciation has been properly taken care of, there will be resources available when the machinery does wear out, with which to replace it. It sometimes happens that a piece of equipment used in the generation and distribution of electrical power is discarded and replaced before it has reached the end of its useful life. This is due to modern improvements in apparatus which make it cheaper in the long run to discard a partly worn out machine and replace it with modern apparatus which will lower the ultimate cost of production.

The item of overhead expense consists of the total amount of labor necessary to generate and distribute the electrical power, office expense and miscellaneous expenses which are very small and which necessarily vary with different central stations. The taxes and insurance items are so well understood that no further mention need be made of them.

The second part of the cost of production, namely, that cost which varies with the amount of power generated, consists largely of the cost of fuel. This item has a very important bearing on the cost of production and since fuel costs have increased so rapidly during the last two an entire telephone line, subjecting all of the subscribers on the line to a hazardous condition. This hazard may be reduced so that there is very little danger of serious shock by installing an arrestor having heat coils and spark-gaps at each farm telephone. In case of a cross between a telephone line and transmission line, the heat coil would automatically disconnect the telephone from its line and the spark-gap would place a positive "ground" on the transmission line, making it much less dangerous. This latter feature would, however, be of very little value unless the ground connection of the arrestor was made in an approved manner. This consists principally in installing the ground rod in such a way that it extends into moist earth at all seasons of the year.

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The second part of the cost of production, namely, that cost which varies with the amount of power generated, consists largely of the cost of fuel. This item has a very important bearing on the cost of production and since fuel costs have increased so rapidly during the last two or three years, it is only reasonable to expect this increase to be reflected in the rates. This is why most of the contracts recently made include a fuel clause which causes the rates to vary in accordance with the variation in the cost of fuel delivered at the plant. There are a few other items included in this part of the cost such as lubricating oil and the expenses of operating auxiliary apparatus, but these are usually small and relatively unimportant.

A review of the items which go to make up the total cost of power at the point where it is sold, shows that each customer should bear his proportionate share of this total cost. Since a large part of this total cost is made up of items which do not depend on the amount of power used, but upon the cost of a plant which is capable of supplying the maximum demand that will be made upon it, it is reasonable to think of the cost of power to a customer as being made up of two parts. One of these parts could logically be called a "demand charge" and the other an "energy charge". The justice of such a rate is obvious. Electricity is something which cannot be generated and stored until it is needed, but must be generated at the time it is used. With this in view, it is no more than fair that the customer who asks the central station to hold itself in readiness to supply him with a large amount of power at any time he may wish to use it, should be asked to pay more than the customer who wants only a small amount of power.

One way in which this demand charge may be somewhat reduced, is for the farmer to arrange to use smaller motors, but operate them for a longer period of time. This will also help to keep down the transformer capacity on the line which in turn will reduce the core losses and improve the power-factor of the system. Regardless of the method that is used in charging for rural service, electrical energy is going to cost more when delivered to farmers than it does when delivered to city customers. The chief reasons for this are that the electrical losses will be higher, the low power-factor of rural lines will make it more difficult to render efficient service and the necessity for holding a portion of the central station capacity in readiness to serve a motor load which may be called for at any time during the day

There will doubtless be instances when the rates asked for rural service will appear to be excessive. This will be due perhaps to a comparison with the rates offered in certain other localities and which it is assumed are sufficient. Too much dependence cannot be placed in a comparison of the rates in one place with those of another, for rates should be based on local conditions, and these vary widely with different central stations. Another reason why a comparison of the rates in different localities is not dependable. is that some central station operators like some farmers, do not know how much it is costing them to produce the product which they are selling, and therefore are apt to sell their goods at a price which is below the cost of production.