

1116

T H E S I S

Farm Home Economics

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## Outline

### Farm Home Economics

- A Beautifying Surroundings
  - 1 Outside
    - (a) by vines, flowers, trees & shrubs
    - (b) by clearing away unsightly places
    - (c) by well kept lawns & fences
  - 2 Inside
    - (a) by good taste
    - (b) by good arrangement
    - (c) by simple daintiness
- B Pleasures and Recreations
  - 1 Books & music in the home
  - 2 Observance of legal holidays
  - 3 Certain days set apart for pleasure
  - 4 Short journeys to the city
  - 5 Fishing, Hunting & Nutting Excursions
  - 6 Participation in social affairs
  - 7 Simple entertainment
- C Conveniences & Labor Saving Devices for
  - 1 Lessening steps
  - 2 Lightening Work
  - 3 Saving time
- D Planning Kitchen as to
  - 1 Size
  - 2 Light
  - 3 Ventilation
  - 4 Convenience
  - 5 Work facilities
  - 6 Furnishings
- E Diet for Farm Life
  - 1 Nutriment required in
  - 2 Economy of as to
    - (a) price
    - (b) time
    - (c) effort
  - 3 Common Errors in food
    - (a) In selection of food
    - (b) In cooking of food
- F Use of a System
  - 1 By keeping accounts
  - 2 By Planning menus and (3) By planning day's work .

### Farm Home Economics

The United States has always been an agricultural nation. As growth has proceeded the suburban element has gradually wended its way westward until now, all over the country we find farms and farmer's homes. In 1903 there were 5,739,657 farms and they have been increasing steadily since that time.

Statistics say that the majority of these farms are worked by the owner himself, that his money and all his interests are expended here. For the ordinary farmer it requires most judicious management to make the money he may have cover all running expences. This is a problem that he must needs face squarely.

First, let us consider, This farm is the home so it must be home-like. The bare yards without flowers, grass or shade ; rough, unpainted houses set down anywhere convenient with rubbish strewn every where are common enough to be familiar to every one. But what is the necessity? It would be just as easy to plan the house first and then build it accordingly. It might just as well be placed in some position where it could appear to advantage. There may be nothing but the smallest and plainest kind of a structure but it is worthy of at least this much attention.

If paint cannot be applied a few vines will do wonders in a season and make a bower of beauty out of the most unattractive foundation. But we are going to consider economy as well and that will urge paint as one of the first considerations as a means of preservation to say nothing of it as a beautifier. Now if one intends to paint the house that does not necessarily mean the application of some atrocious color. Somthing soft and harmonious is just as cheap and satisfies the artistic eye as well as eases the mind about the aconomic question. Farmers are no more barbarious

in their tastes than other people but they think "It doesn't matter, I haven't time to bother" and that is about all the attention they give the matter.

Grass is easily started. Trees can be planted some odd rainy day and will make surprising growth in a few years changing the appearances of the whole place. Flowers and shrubbery are added with little trouble and require little attention. It is advisable on the farm to so plant the shrubbery that it will in no way hinder in the care of the lawn.

Unsightly refuse heaps are often seen and sometimes indeed seem to cover the whole farm. These should be cleared away and in the future there should be definite place for anything worth saving and the rest destroyed before it can accumulate as trash.

Good fences add an air of thrift to any farm. They define the limits of the yard and protect it from the ravages of stock. If the yard is neat and well kept we can almost be sure of the inside as far as neatness and cleanliness goes.

Sometimes we have seen houses that impressed us as painfully neat and clean yet, they seemed bare and unattractive. A little rearrangement or at most the same money differently spent would have entirely changed the appearance of the house. The idea of keeping the parlor shut up as well as everything else enjoyed by the family is wearing itself out but even yet this prevails to a surprising extent in farming districts. If the home is going to be a pleasant place to spend leisure time in ; if it is going to be able to hold the young people it must be attractive.

Recreation and amusement are essential to every one, old as well as young. The farm offers much in the way of simple pleasures and they are safer and purer by far than those of the city which we often foolishly envy.

First, there must be an abundance of books and music. These alone will cultivate and refine the taste as few things can do. Legal holidays should be observed, they should be made days of festivity and happiness, the foundation of pleasant memories. Certain days should be set apart for pleasure and really enjoyed. It is only human to desire that life should hold something more than plain work. To work that one may have the necessities of life, in order that one may work again to gain enough to live another day is not enough to justify living. These times off keep one from getting into a rut where life is all narrow, hard and monotonous,

Country life at best is quiet and secluded so occasional trips to the city are refreshing and give one new enthusiasm and push. There are always fishing, hunting and nutting excursions that may be planned. These times may be made profitable for stores of supplies can be laid in that will last for some time. The little neighborhood affairs should receive due attention. We cannot live independent of our neighbors so it is best to have friendly intercourse with them. If we find them uncongenial we may do much to brighten their lives.

All this involves a way to go. No woman in the country should allow herself to be so helpless that she cannot drive. She may then take herself when her surroundings become monotonous and they do become so if there is no variation. Physicians say that the majority of insane women come from farm homes due to the monotony of their lives.

Last, but not least comes the pleasure that may be taken in the entertainment of friends. This is indeed a privilege but so many tired housewives are all worn out in the preparation until there is no pleasure in the reality. Simple meals are much better than the large affairs which contain a little of everything to eat on the farm which are so hard to prepare.

Even at best the ordinary farmer's wife has a busy time. There is always work ahead as far as she can see so she needs all the conveniences possible. There are infinite steps always but these may be lessened if she has the proper things with which to work. The farmer no longer cuts his grain with a scythe. No more should she wash on the old washboard. She needs a washing machine, a boiler, wringer and all the other laundry equipment. There should be a separator for the milk, one of the churns that will bring butter in a reasonable time. It is still better if she can patronize a creamery and thus eliminate the churning altogether. She needs ice to lighten her labor in the hot summer weather.

The cellar must be convenient and kept perfectly clean and pure for we cannot afford to risk health by allowing germs to accumulate in damp, dark, dirty places. Ventilation should be free. With a little added expense the house may be plumbed and this will save much labor. At any rate no farm should be without pumps for drawing water in the old back breaking way takes too much time and strength. A cistern is a practical addition.

Every housewife appreciates a good range. This is almost an absolute necessity. Nothing is so exasperating as to try to cook with a stove that will smoke or an oven that will not bake. It is a waste of patience, time and strength to say nothing of the poorly cooked food. There are innumerable little devices that may be employed to aid the busy housewife. Some of them are perhaps convenient only for her individual self and the need will appear as the work is arranged. They do not necessarily need to be expensive. Often with ingenuity and perhaps a very little expense a successful article may be made which for usefulness rivals the best manufactured article in the market.

There are farms and farms that have only poor and meager little

gardens, with little or no small fruit and some makeshift for an orchard. now few things are quite so good for the farmer to eat as fresh fruit and garden vegetables. But he says he hasn't time to bother, and so it goes. Gardens do take time but they pay well and so do small fruits. There is always a market for all such surplus material near cities and this makes quite a considerable addition to the family funds. The grocery bills will be found to diminish somewhat and drug bills more while the family will be healthier and consequently happier as a result of the variation in the diet.

Of all rooms in the house the kitchen is the most important. here it is that so much of a woman's time must be spent so it behooves her to make this place as pleasant a spot as possible. Most farmhouses of today possess a dining room. The big kitchens of our forefathers are things of the past. Large kitchens are not practical under present conditions for they mean spreading of the <sup>work</sup> over more space and hence more steps. Neither do we want a little box of a kitchen where it is almost an impossibility to turn around. There is a happy medium with things so condensed however, that it is easy to get a meal together and yet nothing is crowded. There needs to be plenty of light and air for at best the kitchen gets warm and uncomfortable in the summer time. There must be windows to give abundance of air.

The range should be placed with due regard to the dining room and the rest of the furniture accordingly. The housewife does not want to stand by the hot stove to wash dishes and neither does she want her bread and moulding boards too close. A table by the range furnishes a convenient resting place for the various cooking utensils.

The floor is most serviceable of hard wood and may be simply oiled or covered with linoleum. The latter probably involves less labor to keep it clean. An oil or gasoline stove is a means of lightening work. It is

thus easy to get a light meal without heating up the entire house. The expense is really less if we consider the amount of fuel which is wasted when a big fire is built in the range to do a little work. There should be room for a working chair for often there are a few spare moments which may be given to rest. A clock may be considered as a necessary part of the kitchen equipment.

The sinks must be scrubbed daily to avoid accumulations of filth which encourages vile odors. It is so easy to clutter up the kitchen with unnecessary unused articles which collect with other rubbish. The closets and cupboards need weekly going overs at least. The many shelved and drawered kitchen cabinets so widely advertised just now are rather to be avoided because they are so difficult to clean.

Then comes the question of keeping up the day's work. So often we let the work push us instead of pushing the work. Dirty dishes should not be allowed to stand at the sink. They can, as a rule, be washed up while the meal is cooking. When clean they should be into their own places. It is a good plan to find daily experience the place where the utensil is most frequently needed and then make that particular place its own and see that it is always put there.

From an attractive kitchen one would naturally expect attractive food. Since health and strength depend so much upon the food we eat we see the necessity of proper food, as to kind, quality and quantity. The farmer does heavy work and hence requires heavy food. Though he may eat astonishingly large quantities it is better to have the food of a nutritious and somewhat condensed form that the stomach may not be overburdened.

The ordinary farm diet is not expensive. But often the food is not appetizing and only extreme hunger even makes it palatable at all. We may consider food economically with regard to three things, price, time and

effort.

Price is the first because without the wherewithall to purchase we can do nothing. The average farmer has to take a cheap food but this does not mean that he must buy a poor grade. Rather he should have the best grade of the cheaper foods. Often the fancy prices are only for flavor and extra decorations. It does not pay however to buy food merely because it is cheap if it does not contain nutriment accordingly. Sometimes when thus considered we find the more expensive foods the cheaper. Then it pays to buy the higher priced goods.

The time required for preparation must be taken into consideration. The busy woman who has all the other household work to do cannot spend much time doing elaborate cooking. She must choose the dishes that are simplest and easiest to cook. She can often keep the cooking going and tend to her other work as well. Her strength will not permit elaborate dishes even if there were time. It is only when a food offers the minimum cost, with a minimum outlay of time and strength for preparation, combined with a "high food value and tempting appearance that it is in every sense economical.

So few women buy well. This is in a large measure due to ignorance for they do not know the value of different foods from the nutritive standpoint. Often they spend money enough and yet investigation finds the family underfed. Sometimes these investigations show that the groceries themselves are practically just what is needed, that they contain the necessary food principles in somewhere the right proportion and yet the family is not thriving. This leads us to suspect the cooking.

So many times we have seen heavy, soggy bread, vegetables and meat swimming in grease, food underdone, little or no fruit and various other unpalatable things until we marvel that the farmer can eat at all. Farmers



## Sunday

Breakfast

Raspberries

|                  |                 |
|------------------|-----------------|
| Cracked Wheat    | Cream and Sugar |
| Sliced Cucumbers | Scrambled Eggs  |
| Biscuit          | Coffee Butter   |

Dinner

|                 |             |
|-----------------|-------------|
| Fried Chicken   | Brown Sauce |
| Mashed Potatoes | Lettuce     |
| Bread           | Butter      |

Bavarian Cream

Coffee

Supper

Bread and Milk

Fruit Cake

Tea

(usually informal)

## Monday

Breakfast

Apples

|             |                 |
|-------------|-----------------|
| Rolled Oats | Sugar and Cream |
| Boiled Ham  | Potatoe Cakes   |
| Muffins     | Jelly           |

Coffee

Dinner

Tomato Soup

String Beans Creamed Corn

Boiled Potatoes

Bread and Butter

Blackberry Pie

Coffee

Supper

Creamed Chicken

Boiled Rice Sliced Tomatoes

Bread Butter Jam

Cake

Tea

## Tuesday

Breakfast

Blackberries

Hominy

Sugar and Cream

Bacon

Creamed Potatoes

Bread and Butter

Coffee

Dinner

Corn on Cob

Baked Potatoes

Baked Beans

Brown Bread

Apple Sauce

Coffee

Supper

Sliced Tomatoes Salad Eggs

Cold Boiled Ham

Bread

Butter

Cookies

Tea

## Wednesday

Breakfast

Cream of Wheat

Sugar and Cream

Raspberries

Baked Eggs

Biscuit

Coffee

Dinner

Corn Soup

Boiled Meat

Mashed Potatoes

Cottage Cheese

Cole Slaw

Creamed Onions

Rolls

Butter

Orange Tapioca

Coffee

Supper

Fried Potatoes

Scrambled Eggs

Sliced Tomatoes

Bread

Butter

Cookies

Milk

## Thursday

Breakfast

Blackberries

|                |        |
|----------------|--------|
| Corn Meal Mush | Milk   |
| Bacon          | Eggs   |
| Graham Gems    | Butter |

Coffee

Dinner

|             |              |
|-------------|--------------|
| Roast Duck  | Stuffing     |
| Brown Sauce |              |
| Potatoes    | Creamed Corn |
| Bread       | Butter       |

Baked Apples

Coffee

Supper

|                |                    |
|----------------|--------------------|
| Potato Balls   | Scalloped Tomatoes |
| Radishes       |                    |
| Cottage Cheese |                    |
| Bread          | Butter             |

Tea

## Friday

Breakfast

|             |                  |
|-------------|------------------|
| Apple Sauce | Fried Mush       |
| Eggs        | Sliced Cucumbers |
| Biscuits    | Butter           |
| Coffee      |                  |

Dinner

|              |                 |
|--------------|-----------------|
| String Beans | Fat Meat        |
| Lettuce      | Sliced Tomatoes |
| Potatoes     | Bread           |
|              | Butter          |
| Rhubarb Pie  |                 |

Supper

|                              |          |
|------------------------------|----------|
| Creamed Macaroni with Cheese |          |
| French Fried Potatoes        | Radishes |
| Cold Duck                    |          |
| Apple Sauce                  | Cake     |
| Tea                          |          |

Saturday  
Breakfast

|                |                 |
|----------------|-----------------|
| Cream of Wheat | Sugar and Cream |
| Beef Steak     | Brown Sauce     |
| Radishes       |                 |
| Bread          | Butter Jam      |
| Coffee         |                 |

Dinner

|                 |              |
|-----------------|--------------|
| Mashed Potatoes | Creamed Peas |
| Pressed Chicken |              |
| Cooked Tomatoes | Cucumbers    |
| Bread           | Butter       |
| Apple Pie       |              |
| Coffee          |              |

Supper

|                |              |
|----------------|--------------|
| Potatoe Balls  | Beet Pickles |
| Cheese Souffle | Hash         |
| Rolls          | Butter       |
| Doughnuts      |              |
| Buttermilk     |              |

It is best to arrange a general program for the day's work for there is always a certain amount that must be done regardless of everything else. A simple method is given below

Get up and dress     5 A. M.  
 Air beds, open windows  
 Open dining room & kitchen windows  
 Remove ashes  
 Lay fire  
 Black range  
 Fill kettles  
 Start breakfast  
 Brush floor  
 Set table  
 Dress children  
 Finish Breakfast     6 A. M.  
 Clear up dishes, put to soak  
 Straighten & brush dining room  
 Straighten living room

Wash dishes  
 Clean lamps  
 Straighten kitchen  
 Make beds 9 A. M.  
 Start dinner 10.30 to 11.00 A. M.  
 Partially prepare supper  
 Dinner 12 M.  
 Straighten dining room & sitting room  
 Wash Dishes  
 Straighten kitchen 1.30 P. M.  
 Start evening work 5 P.M.  
 Start supper 5.45 P. M.  
 Supper 6.30 P. M.  
 Straighten dining room  
 Wash dishes  
 Straighten kitchen 8 P.M.  
 Read &c  
 Go to bed 9 P.M.

This may be taken as the rule. The heavy work may then be put in as it is necessary. It might be arranged thus :

Mon. - Straighten after Sunday - Churn  
 Tues - Wash  
 Wed - Iron - Bake  
 Thurs Sew - Mend -Call -Shop.  
 Fri - Sweep - Scrub.

In this way it is possible to economize time and strength. It leaves more room for pursuit of the intellectual things of life.

It is proper for every woman on the farm to make the most of each opportunity. It will help her to keep up with the world and she will then bring her family up with her. With their cooperation the farm with its natural charms and modern conveniences will rival any city residence. Farm life is no longer to be dreaded. It is instead a happy lot and a vocation that today has much to offer. Such being the case we may expect much of our farm homes of the future

Graduating Thesis.

"THE TRANSMISSION OF ELECTRICAL ENERGY".

Richard Reece,

Kansas State Agricultural College.

1906.

Department of Electrical Engineering.

## Thesis- Outline.

Subject: Transmission of Electrical Energy.

Introduction: The Scope of the Subject.

### Discussion:

- I. Transmission in general.
- II. Advantages of Alternating Current for Transmission.
- III. Factors included in Transmission.
  1. The Line.
    - a. Aerial lines.
    - b. Underground lines.
  2. Line construction.
  3. Relative merits of Copper and Aluminum for conductors.
  4. Variation of weight of Copper with voltage.
  5. Variation of weight of Copper with distance.
  6. Effect of resistance of conductors.
  7. Line capacity.
  8. Line induction:- Calculation.
  9. Method of placing wires.
  10. Calculation of size of wire.
  11. Calculation of weight of wire.
  12. Calculation of line loss.
  13. Relative amount of copper required for different systems.
    - a. Single phase.
    - b. Two phase.
    - c. Three phase.
  14. Relative cost of pole and tower construction.
  15. Insulators.

16. Lightning arresters.

a. General Electric arrester.

b. Westinghouse arrester.

IV. Hydraulic Plants.

Comparison of cost with-

a. Steam plants,

b. Water turbines.

V. Power Station Apparatus.

1. Generators.

2. Transformers.

3. Switches.

VI. Sub-stations.

1. Purpose of sub-stations.

2. Apparatus.

a. Motor-generator.

b. Rotary converter.

VII. Conclusion.

## Transmission of Electrical Energy.

The subject of electrical transmission of power is a very broad one. As with other branches of electrical engineering it is only in recent years that any great advances have been made in the means employed for transmission of electrical energy. While this advance has been very rapid there is still a large field for development.

In treatment of this subject, the different methods employed and their application to most efficient systems to be installed, for given service, the preparation of conductors and the calculation of their size, together with their proper installation will be considered.

Electrical power transmission may be divided into two classes: - long distance, for which high tension alternating current is exclusively used, and short distance, for which either direct or alternating current is adapted.

For short distances the direct current predominates, perhaps on account of the fact that direct current machinery was first developed and a large number of manufacturers are engaged in the building of direct current machinery.

Both types of currents have their advantages and disadvantages and engineers are divided in their opinions as to which has the greater value. Only high tension transmission will be considered in this production.

Direct current has some points of superiority. Its use is not attended by inductive effects and no appreciable capacity effect. It is not so likely to puncture the insulation, and cause short-circuits and arcing. Direct current machines are limited to about 1000 volts; voltage much in excess of this will cause vicious sparking at the

commutator, which not only inaugurates a loss of energy, but soon destroys the commutator, or calls for repairs. Aside from the sparking at the commutator, mechanical limits of armature peripheral velocity, current density, flux-density, and temperature elevation limit machine voltage. Furthermore service conditions demand other voltages than that of the transmission line, and the direct current transformer or dynamotor is very expensive and not very efficient.

The ease by which alternating current can be transformed to any desired voltage, and the high efficiency of the transformer makes it very desirable. The use of alternating current is attended by the effects of capacity and inductance, and up to the present time the use of the alternating current motors has been only fairly successful. The transformer used for alternating current work is only of very moderate cost, quite durable and efficient; it makes possible transmission at high voltages with accompanying small currents, small line wire, in fact a line construction of low cost.

The line plays a very important part in electrical transmission of energy, for on it depends the continuity of service. In its relation to the plant as a whole, it is to be considered as a conductor. Whenever an electrical current traverses a conductor there is a loss of energy due to the fact that all substances have an electrical resistance which must be overcome. The current that will flow equals the electro-motive force between the points, divided by the resistance, or  $E = CR$ . This loss in volts compared with the original voltage shows the percentage of energy lost. From Ohm's law,  $E = ER$ , we have  $CE = C^2 R$  or watts loss varies as the square of the current, halving the current divides the loss by four and the percentage loss by two, since the total energy is proportional to the current, the electro-motive

force being fixed.

It is easily seen that the voltage used is an important factor in the cost of the line. For a fixed percentage of loss, doubling the voltage will evidently divide the amount of copper used by four, since the current will be reduced one half for the same supply of energy.

The above discussion shows that the amount of copper required to transmit a given amount of energy at a fixed percentage of loss, will vary inversely as the square of the voltage. If the distance of transmission is doubled the area of the conductor will have to be doubled; and since the length has doubled the weight of copper has increased four times. This shows that the weight of copper increases as the square of the distance, the same energy being transmitted at the same percent efficiency. So it is easy to see the advantages of employing high voltages for transmission over considerable distances.

As regards the character of transmission lines, the usual plan is to use pure hard drawn copper wire supported on wooden or iron poles by suitable insulators; the tendency at present is to replace the poles by steel towers. Occasionally underground constructions are necessary, and frequently an aerial transmission line must be coupled to an underground distribution, owing to municipal regulations. When only moderately high voltages are employed, insulated wire is frequently used; in cases of high tension transmission, say 10,000 volts and upward, no practical insulation can be depended upon and should not be used, both from a standpoint of economy and of personal safety. The feat of cable insulation has been accomplished for pressures as high as 25,000 volts, and this limit could probably be exceeded, but the cost of such work is very high and it is also very difficult to locate and remedy faults that may occur. An overhead line is so much

easier to construct and maintain that it appears at present that power transmission in general will continue to be carried on by this method for some time to come. In fact the cost of insulating underground cables for very high voltages like those now coming into use, 60,000 volts or more, makes it desirable to avoid underground transmission lines.

A word should be said concerning the relative properties of certain metals as conductors. With the exception of silver, pure copper is the best conductor among the metals. Commercial copper wire is of somewhat variable conductivity, due to the small proportions of other substances it contains. The presence of 0.1 per-cent of iron reduces its conductivity about seventeen per-cent. The best grades of standard wire have a conductivity of about 98% of that of chemically pure wire. On account of the low tensile strength of copper wire, (about 35,000# per sq.in.) efforts have been made to exploit various alloys of copper on the theory that their greater strength would more than counter-balance the lessened conductivity and greater cost, by requiring fewer supports.

Aluminum has been suggested as a substitute for copper for wire. It has 0.6 the conductivity of copper. Owing to its very low specific gravity its conductivity is very high when compared with copper on the basis of weight. It has about one half the weight of copper for the same conductivity. The tensile strength of aluminum is slightly less than that of copper, but comparing wires of equal conductivity, the aluminum wire is much the stronger of the two. Aluminum wire being larger than copper for the same conductivity has a greater inductance and capacity and is more exposed to the effect of storms. Its coefficient of expansion is about 1.4 times that of copper, so it has a greater tendency to sag in hot weather. This property is in itself a great

objection to its use on the transmission line. It will however, prove a good substitute for copper, and will undoubtedly be used quite extensively if the prices of copper advance much above the present value.

The resistance of electrical conductors is expressed by the formula,

$R = L/A \times K$ , where  $R$  = total resistance of the conductor,

$L$  = total length of the conductor,

$A$  = area of the conductor,

and  $K$  = a constant depending on the material used.

For cylindrical conductors  $L$  is usually expressed in feet and  $A$  in circular mils. By a circular mil is meant the area of a circle .001 in. in diameter.

The effect of resistance in a conductor is three fold:

1st. There is a drop in voltage:  $E = IR$ .

2nd. There is a loss of energy proportional to the resistance and the square of the current.

3d. There is a heating of the conductor due to the energy lost.

The temperature of a conductor will rise until heat is lost at a rate equal to the rate it is generated, so that a conductor is capable of carrying only a certain amount of current at a given allowable temperature rise.

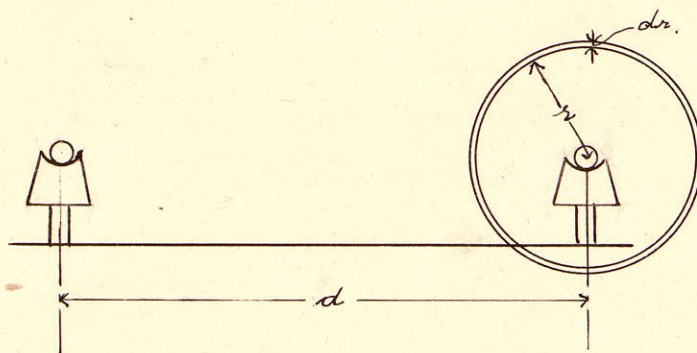
#### Capacity.

Conductors used for electric power transmission form with the ground or with neighboring conductors, condensers which have an appreciable effect in long lines. The wires correspond to the condenser plates, and the air to the di-electric. When lines are close together the capacity effect is greater. Because of its capacity effect, a line which is unloaded takes a current when an alternating electromotive force is impressed upon it. If the capacity be  $C$  microforads, then  $E$  volts at a frequency of  $F$  would send a charging current

$I = 2\pi FEC \cdot 10^{-6}$  amperes.

### Line Inductance.

The varying flux which is set up between the wires of a transmission circuit by the current flowing in them, gives rise to a mutual induced counter-electromotive force. The inductance per unit length of single wire is equal to the flux per unit current, which links a unit length of the line. The reaction is greater the smaller the wires and the farther they are apart, and is proportional to the length of the line and to the frequency. To determine the value of line inductance, consider a single phase line with wires  $R$  centimeters in radius  $D$  centimeters apart, carrying a current  $i$ . Let the cross-section of the line be represented as in figure.

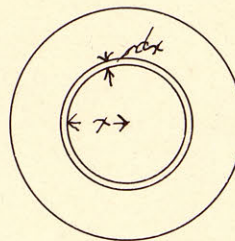


The flux  $d\phi$  which passes through the element  $dr$  wide and of unit length is equal to the magneto-motive force divided by the reluctance, or

$$d\phi = \frac{4\pi i}{2\pi r} = 2idr/r;$$
 Integrating for values of  $r$  between  $d-r$  and  $r$  we have  $\phi = 2i \log (d/r).$

There is some flux which surrounds the axis of the wire and lies within the metal. Represent the wire by the circle. The current inside the wire is  $\frac{x^2}{R^2} i$ , and the magneto-motive force it produces is

$\frac{4\pi x^2}{R^2} i$ . The flux which it produces links itself with but  $\frac{x^2}{R^2}$  ths. of the wire.



The flux that links the circuit is

$$d\phi_2 = \frac{2\pi^3 i}{m R^4} dx. \quad \text{Integrating between 0 and R ;}$$

$\phi_2 = \frac{i}{2m}$ . For copper wire  $m = 1$ , hence the total flux linked with the line is

$\phi_1 + \phi_2 = 2i \left( \log.e \left( \frac{d}{r} \right) + \frac{1}{4} \right)$ . And as the inductance is the flux per unit current,  $L = 2 \log_e \left( \frac{d}{R} \right) + \frac{1}{2}$ .

Reducing to henrys per mile of wire,  $L = (80.5 + 740 \log \frac{d}{R}) 10^{-6}$ .

Size of wire.

By Ohm's law we have  $R = E \div C$ , and remembering that  $R$  = length in feet times the resistance of one foot of wire one mil in diameter, divided by the area in circular mils, we obtain, since the resistance of one mil-foot of wire is about 11 ohms,  $R = 11 L$  divided by circular mils. Or taking the total length of wire as twice the distance of transmission in feet,  $R = 2 D \times 11$  divided by circular mils, where  $D$  = the distance one way.

Substituting in Ohm's law, Circular mils =  $\frac{2D \times 11C}{E}$ . This gives the area of the wire for delivering any current over the distance with any loss  $E$ , in Volts. The corresponding size and weight of the wire can be found in any wire table.

A similar equation can be constructed for expressing the weight of wire required. It happens that copper wire 1000 circular mils in area weighs nearly 3# per thousand feet. Taking  $D$  in thousands of feet, we

have

$$\text{Wt.} = \frac{2D \times 33C}{E}, \text{ or for the total length of wire}$$

$$W = \frac{4D^2 \times 33C}{E}.$$

The three phase system is ~~not~~ used for long distance transmission partly on account of the saving in copper. Polyphase machines can be constructed more cheaply for a given output, than single phase machines because of a better utilization of the winding space on the armature. The two-phase and the three-phase systems are the only ones in common use for power transmission. The amount of copper required for the different systems, assuming the weight of copper for a single phase two wire system to be 100%, is as follows:

Single phase two wire system.....100%

Two-phase, four wire system.....100%

Three-phase, three wire system..... 75%

This assumes the voltage at the receiver end to be the same in every case, the maximum voltage having different values depending on the system used. The three phase, three wire system is preferable to the two wire system for most purposes.

As an example of the way in which the relative amounts of copper are calculated, take the three phase, three wire system. Let  $P$  = power transmitted and  $P'$  the percentage of the loss of energy.

$E$  = voltage of the receiver end.

$I$  = current in one line, single phase system.

$I'$  = current in one wire, three phase system.

We have for the single phase, two wire system  $P = I E$ .

For the three phase, three wire system  $P = \sqrt{3} I' E$ .

$$\text{Hence } I E = \sqrt{3} I' E ; I' = \frac{I}{\sqrt{3}}.$$

The lost energy in the two wire system =  $PP' = 2I^2 R$  where  $R$  = resistance of one conductor. The loss in the three wire system =  $PP' = 3(I')^2 R$ .

where  $R'$  = the resistance of one wire.

Substituting  $\frac{I}{\sqrt{3}}$  for  $I'$  we have  $2R = R'$ .

The amount of copper is inversely proportional to the resistance of the conductor, so if  $W$  = weight of one conductor for single phase system, and  $W'$  = weight of one conductor for three phase system,  $W$  will equal  $2W'$ . Two conductors are required in the first case =  $2W$ . Three conductors are required in the second case =  $3W'$ :

$$3W' = 3/2 W; \frac{3W'}{2W} = \frac{3W/2}{2W} = 3/4 = 75\%.$$

A study of the problem of long distance line construction for electrical transmission has been made by Signor Guido Semenza. He holds that wires should be arranged geometrically at distances determined by electro-magnetic laws. Although there are many possible arrangements, the most desirable is the one in which the wires are placed at the angles of an equilateral triangle. This arrangement gives the longest allowable span. The support must combine certain mechanical properties with electrical resistance. As the supports may be placed different distances apart, it is necessary to determine that distance which is the most advantageous. This is done by treating the problem as has been done in determining the best design for bridges and other similar structures. In selecting the route to be followed, it should be borne in mind that, although a straight line may be less expensive to construct, since the distance is shorter, and special poles are not needed, the cost of right of way over such a route may make the total cost of the straight line greater. Long spans with few poles are, in general, advantageous, and these can be used with deep sags. The advantages of iron towers, which are rigid at right angles to the line, and flexible in the direction of the line, should be noted. In case of a break in the line such towers will bend and transmit part of the strain to neighboring towers. A comparison is made between two designs

of a line, one using wooden poles placed 35 to the mile and the other using iron towers placed 9 to the mile. The expense of the wooden poles is found to be \$245. per mile, \$168. for 210 insulators, \$40. for erection, \$120. for right of way, and \$56. for cross-overs, total \$629. For the tower construction, the cost of towers per mile is \$360. erection \$90. insulators, \$64. erection \$40. right of way \$120. total \$674. Thus it is seen that the expense for erecting the two lines differs but little. It is thought that the tower construction will be much less expensive to maintain; a life of 25 years is thought to be allowable, while for the wooden poles only from 5 to 10 years is allowed.

The transmission line of Gaunajuato, Mexico, is constructed on the steel towers. The plan was not only to replace the wooden poles, but also to increase the span and thus reduce the number of insulators required, which by experiment proved to be the weakest point in the line. The structure resembles the ordinary steel windmill tower, anchored at each corner to a concrete foundation, the distance from tower to tower being from 500 to 600 feet. The tower construction is to be highly recommended for localities where insects have proved troublesome and poles are scarce. The chief objection to their use seems to be the tremendous strain placed upon the insulators.

#### Insulators.

The insulator employed for high tension transmission is usually of porcelain. Glass is sometimes used and has proved fairly satisfactory, especially in the Utah transmission system.

Porcelain insulators are preferred owing to their superior mechanical strength. It is customary to make the insulator in several pieces in order to insure the proper baking of the porcelain, which is difficult in large masses. The insulator is usually tested with about 2 1/2

to 3 times the voltage it is expected to insulate. The failure of the insulator in one way or another, causes considerable trouble in transmission lines.

While the size of the insulators may be largely determined by form, at the same time it should be noted that up to 10,000 volts the insulators, whether glass or porcelain, have a minimum diameter of about 5 inches. A 7 inch insulator up to 25,000 volts, 13 inch up to 40,000 while at 60,000 volts, insulators should not be less than 14 inches at the top.

Lightning is one of the chief sources of trouble in transmission lines. While it is not a continuous risk like the insulator, yet it is responsible for a considerable amount of trouble, owing to the fact that no apparatus has proved entirely satisfactory as a preventative. A lightning stroke along the line may cause a large amount of damage to the apparatus. It frequently shatters the insulators and poles. Not only are strokes along the line to be dreaded, but in times of severe electrical storms, induced charges along the line may become of such magnitude as to cause the potential to rise to such values as to puncture the insulators. Perhaps the best safeguard against the lightning is to construct a duplicate line, as it is improbable that both lines will be victims of the same storm.

#### Lightning Arresters.

Lightning arresters are merely devices for giving induced charges an easy path to the ground, at the same time prohibiting the line current from passing out. The arrester consists merely of spark gaps connected in series and joining the line to a ground wire. These gaps do not allow the line current with its normal voltage to pass, but afford a comparatively easy path for lightning discharge on account of its high potential. To prevent an arc being established by the line current

after a lightning discharge has passed and started the arc, some means must be employed to extinguish the arc. In the General Electric Co. arrester, the arc is extinguished by a magnetic blow-out, which is energized by the current that flows through the arrester.

In the Garton-Daniels arrester, a plunger contact operated by a solenoid, opens the circuit as soon as the current begins to flow through the arrester. This plunger operates in a magnetic field which extinguishes the arc.

The General Electric Co. arrester has for up to 2000 volts, two  $1/32$  inch gaps connected from line to earth in series with a high non-inductive resistance. The current is kept low by the high resistance used. For protection against static charges, one half of the gaps are cut out by a bridge connecting the two cylinders which are mid-way between the line and the earth. The arrester thus connected will give the same number of gaps between the lines as from the line to earth. For higher voltages, several arresters are connected in series.

The Westing house arrester for potential up to 2000 volts, has six  $1/32$  inch air gaps, connected in series from line to earth. The cylinders are made of non-arcing metal. No resistance is used when connected to 2000 volt lines. When a higher potential is used, more gaps are put in in series and a resistance is connected in series with the arrester to prevent an excessive current flowing from the generator through the arrester.

At voltages above 20,000 volts there is likely to be a considerable loss of energy, due to a discharge between wires. These discharges are quite noticeable on a dark night. At from 50,000 to 60,000 volts the lines must be well separated, for arcs are likely to strike from wire to wire, producing short circuits.

A large number of plants are transmitting energy at 30,000, 40,000, and 50,000 volts; a few plants at present are using nearly 60,000 volts, and present indications are that they will prove successful. It is the tendency at present to even exceed these voltages, and transmission is being discussed at 90,000 to 100,000 volts. Whether these lines will be put into operation remains to be seen. Surely a point will ultimately be reached at which the saving of copper will be overbalanced by the cost of insulating devices due to increased voltage. This point so far has not been determined, but surely will, as at present, continue to depend upon the amount of power to be transmitted, and the allowable line loss, together with the cost of transformation apparatus.

On account of mutual induction, it is very desirable to run but a single circuit per pole line, especially if very high voltages are used. If more than one circuit is strung on one set of poles, the lines should be transposed at intervals to keep down mutual induction.

Another difficulty in connection with line construction is making a safe entry into the power station and other buildings which the high tension lines must enter. Various plans have been tried, but perhaps the most satisfactory is to use a rather large opening with the wires held centrally in it by good insulators.

#### Distance of Transmission.

The distance that electrical energy can be profitably transmitted, depends upon the amount of power to be transmitted and the price received for it. At the present time several lines are transmitting 100 miles or more, the longest being 250 miles. Owing to the fact that these long lines have been in operation but a short time, very little information is available regarding their performance.

Fifty to sixty cycles seem to be used in a majority of the high tension lines. The Niagara plant, however, transmits to Buffalo and adjoining cities at twenty-five cycles. A large part of the transmitted energy is used for lighting purposes and cycles as low as 25 have proved unsatisfactory for this purpose. The employment of 25 cycles or lower necessitates a frequency changer, thus requiring an additional cost. However, where the transmission line is long and the power to be transmitted is great, it may prove desirable and economical to transmit at low frequency and employ frequency changers.

#### Hydraulic Plants.

Because of the ease with which electrical energy may be transmitted long distances, it has become quite common to locate the generating stations where there is an abundance of water power, and to transmit the energy thus generated to localities where it is needed. The powerhouses now completed or in the course of construction at Niagara Falls are examples of the enormous size such stations may attain.

Before deciding to use water power the following points should be considered:

- 1st. The amount of water power available.
- 2nd. The probable demand for power.
- 3d. The cost of developing this power compared with the cost at other plants using other sources of power.
- 4th. The cost of operation as compared with other plants, and the extent of transmission lines.

Hydraulic plants are as a rule much more expensive than steam plants, but the first cost is more than made up by the saving in operating expenses.

The generators of a hydraulic plant are driven by water turbines.

The water turbines may be divided into two general classes: reaction turbines and impulse turbines.

The reaction turbine may be sub-divided into parallel-flow, outward-flow, and inward-flow turbines. Parallel flow turbines are best suited for very low heads. Their efficiency is about 70%. Outward-flow turbines and inward-flow turbines give a somewhat higher efficiency, usually about 75 to 85%.

Impulse turbines are suited to very high falls. The Pelton wheel is perhaps one of the best known types of impulse wheels. Under favorable conditions, it is claimed that this wheel will give an efficiency of 86%.

#### The Electric Plant.

The first thing to be considered in the electric plant is the generators. A good rule, which may apply to almost all the machinery for power stations, is to select machinery which is considered as standard by the manufacturing companies. There are two good reasons why this rule should be followed: first, reliable companies employ men who may be considered as experts in machine design, and it is their best machines that are standardized; second, standard apparatus is cheaper than other apparatus, owing to larger production, and repairs can be more readily obtained. As to the type of machine, the alternating current generators should be employed for long distance, high tension transmission. Alternating current generators may be purchased, which will give 15,000 volts at the terminals. As a rule it is not a good plan to use extremely high voltages for the generators themselves, but to use step-up transformers, in case very high voltages are necessary.

Machines wound for high potential are more expensive for the same capacity and efficiency, but the cost of step-up transformers and the losses in the same are saved by such machines, so there is a slight

advantage in using high voltage machines. On the other hand, lightning troubles are likely to be of greater magnitude when transformers are not used, as the transformer acts as an additional protection to the machine; and if transformers are injured they may be repaired or replaced with little expense.

### Transformers.

Transformers for stepping the voltage from that generated by the machine up to the desired line voltage, or vice-versa, at the substation, may be divided into three general types according to the method of cooling. Large transformers require some artificial means of cooling. They may be water-cooled, oil-cooled, or air-cooled.

The oil-cooled transformers have their cores and windings placed in a tank filled with oil. The oil serves to conduct the heat to the case, and the case is usually made of corrugated sheet metal or of cast iron, containing deep grooves so as to increase the radiating surface. This type of transformer is especially adapted to high voltages.

Air cooled transformers are usually mounted over an air-tight pit fitted with motor-driven blowers which feed into the pit. The transformer coils are sub-divided so that no part of the winding is at a great distance from the air. The amount of air that passes through the transformer is controlled by means of dampers.

When very large transformers for extremely high voltages are required the water-cooled type is usually selected. This type of transformer contains water tubes arranged in coils in the top, otherwise it is similar to the oil-cooled type. Cold water passes through these tubes and aids in removing heat from the oil.

The relative merits of star and delta connection is somewhat in dispute. Up to 25,000 volts the delta connection seems to be preferred. chiefly because of this connection, a ground along the line does not

necessarily result in a short circuit, and in case of failure of a single transformer the service is not necessarily interrupted. For higher voltages the star connection is usually employed and the neutral point grounded.

#### Sub-stations.

Sub-stations are for the purpose of transforming the high potentials down to such potentials as may be used in motors or lamps, and in many cases to convert alternating current to direct current. Step-down transformers do not differ in any respect from step-up transformers. Either rotary converters or motor-generator sets may be used to change alternating current to direct current. The motor-generator sets consists of synchronous or induction motors, direct connected to direct-current generators, mounted on the same bed-plate. Rotary converters are direct current generators, fitted with slip-rings attached to the windings at definite points. The alternating-current is fed into these rings and the machine runs as a synchronous motor, delivering direct-current at the commutator end.

The rotary converter is not suitable for general distribution in small units. It has the advantage over the motor-generator in point of cost, and in efficiency, as there is but one machine instead of two, and in its effect upon the voltage of the transmission system, compounded to overcome the line drop.

On the other hand the electro-motive force of the direct current delivered by the converter has a more or less fixed relation to the electro-motive force supplied, while the electromotive force of the motor-driven generator is independent of the supplied electro-motive force.

#### High Tension Switches.

Alternating current generators for high voltages usually have oil switches to interrupt the main circuit; that is, switches in which the

contact is made and broken under oil. These switches have been found to be very effective in preventing a destructive spark upon the opening of circuits employing very high voltages. Some of the large oil switches are operated by electric motors or solenoids. The General Electric Co. type of oil switch has the motive power for opening the switch stored up in a spring. The spring is wound up by a small electric motor. This motor operates every time the switch is opened or closed and winds up the spring enough to compensate for the amount it was unwound by opening or closing. Each circuit is broken under oil in a long tube, and these tubes are placed in separate cells, so that there can be no flashing across from one leg of a circuit to another.

Where alternating current generators of low voltages are used in connection with step-up transformers, it is the practice to have the switches for each generator directly in the generator leads, between the generator and the step-up transformer, in the low voltage circuit. The great diversity of opinion, and experience, plainly show that climatic conditions have a marked effect upon transmission systems.

Taken all together, 40,000 to 50,000 volts have proved quite satisfactory; 60,000 or more are successful under favorable conditions. Higher pressures will depend upon the evolution of better insulators than are at present available.

A study of some of the great transmission systems of to-day leads one to the thought that by a few more years of hard study, the electrical engineer will so overcome the obstacles of electrical transmission that we will find ourselves in the midst of the true era of electricity. Then houses will no longer have need of chimneys and all operations will be preformed electrically. Great problems will continue to arise. Other Edisons and George Westinghouses will arise, and our great systems of to-day will be supplanted by far greater systems; ones of

which the most imaginative dreamer as yet has seen no vision.