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FARMSTEAD WIRING

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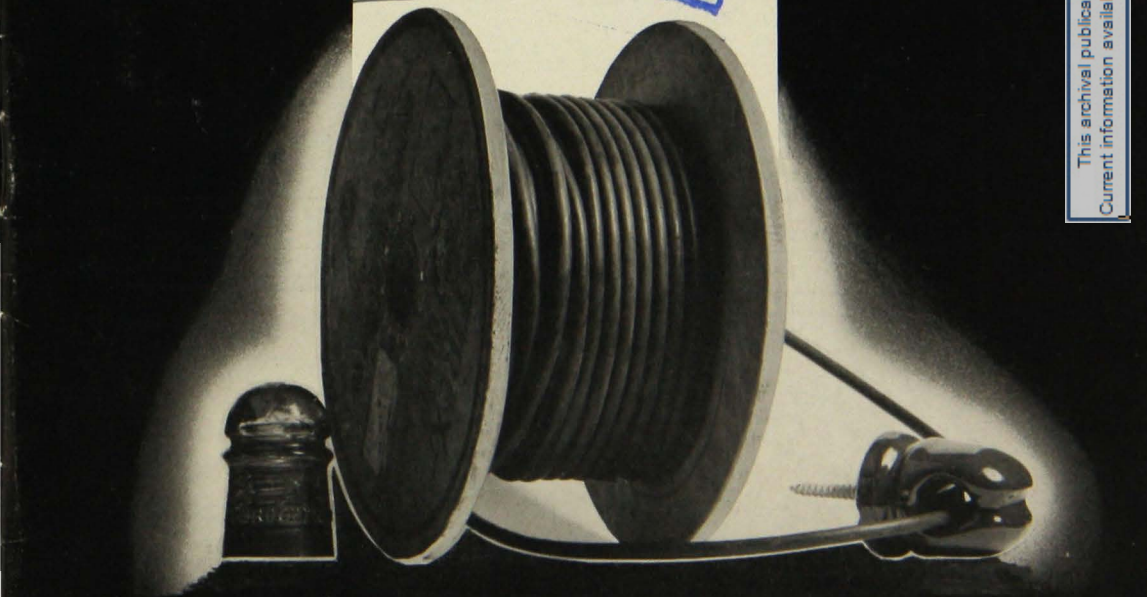


AGRICULTURAL EXTENSION DIVISION—UNIVERSITY OF MINNESOTA

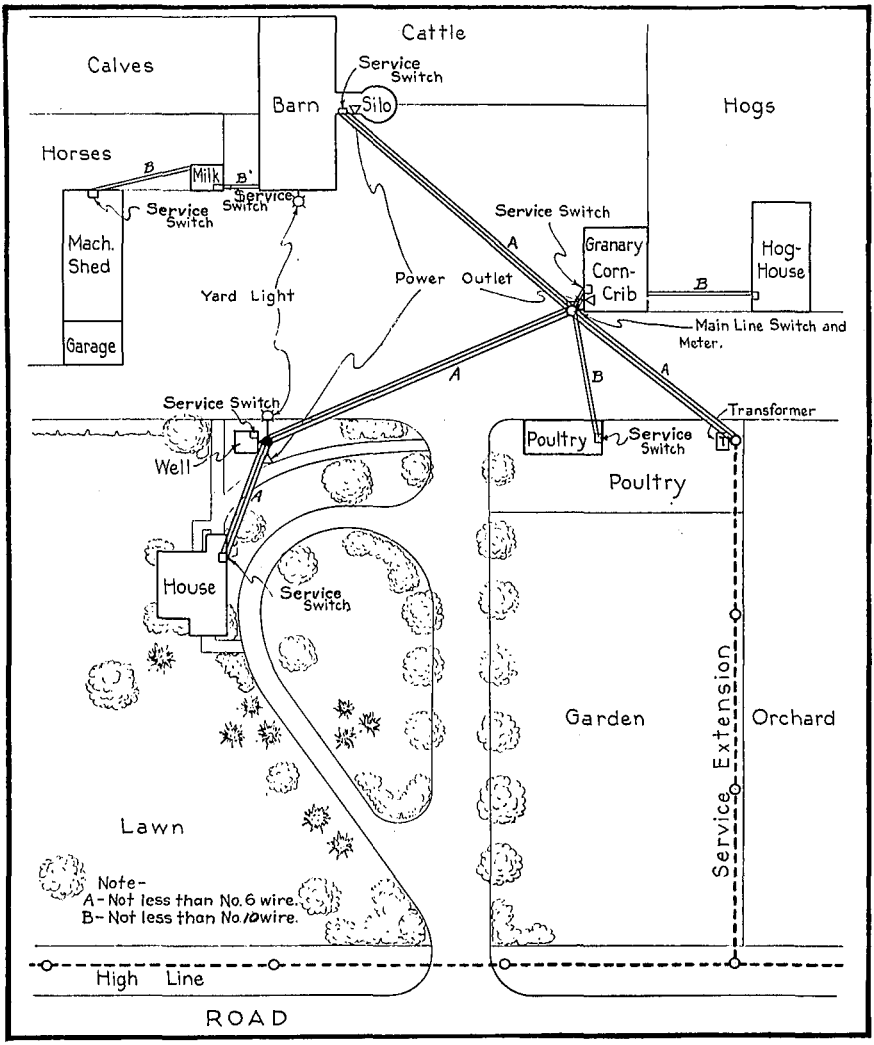


FIG. 1. FARMSTEAD PLAN SHOWING THE LOCATION OF TRANSFORMER AND SERVICE WIRES

THE purpose of this publication is to assist the prospective user of electricity in the choice of the proper materials and methods for wiring buildings on the farm. At the present time there is no state law governing the minimum requirements for electrical wiring. Most of the large cities, some fire insurance companies, power companies, and some of the smaller local governing units have certain requirements which must be complied with before service can be obtained. Before starting to plan the wiring job, find out if any such local ordinances or codes are in effect. Most of the local codes are copies or modifications of the "National Electrical Code" published by the National Board of Fire Underwriters, 222 West Madison Street, Chicago, Illinois. This code is the result of the cooperative efforts of fire protective associations, electrical contractors, architects, and other interested groups to formulate a standard set of recommendations for wiring. Where no local wiring regulations are in effect, anyone contemplating a wiring job should familiarize himself with the National Code recommendations and should insist that all wiring be done in accordance with them.

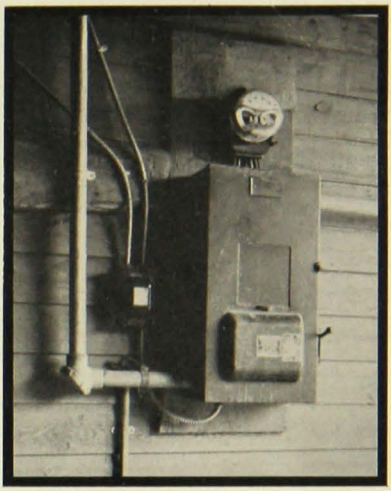
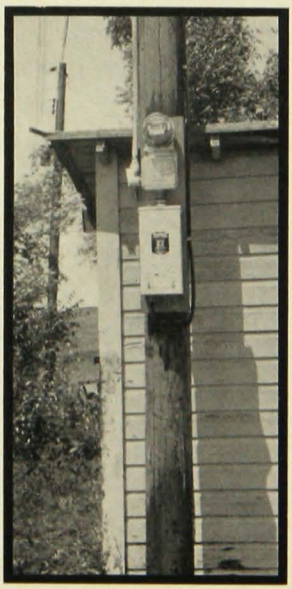


FIG. 2. INDOOR TYPE OF MAIN SERVICE ENTRANCE SWITCH AND METER LOCATED IN A MACHINE SHED

Service wires are carried in rigid conduit. The small cabinet at the left is the service cabinet for the machine shed and granary.



Whether the wiring is to be done for an individual 32-volt plant or for a 110- to 220-volt high-line service, the standards of wiring should be the same. Farm homes which in the past have been served with 32-volt plants may in general be able to change to 110-volt service with the addition of the proper types of entrance switches and ground connections. For the farm yard and farm outbuildings the wiring is usually inadequately insulated and of too small capacity to carry the load for which the higher voltage service may be used.

FIG. 3. NEW TYPE OF OUTDOOR METER AND MAIN SERVICE ENTRANCE SWITCH

The wires from the transformer are carried down the pole in rigid conduit. Service wires for the farmyard distribution from the cabinet are carried in flexible weatherproof cable.

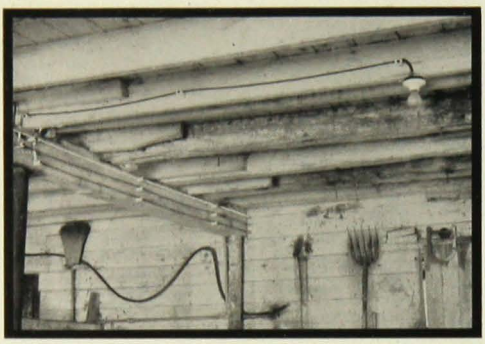


FIG. 4. KNOB AND TUBE WIRING IN A BARN

Note how the wires are protected by running along the girders and joists. The upper white wire at the left is the neutral.

Safety should be the first consideration in a wiring job. The fire risk in buildings equipped for electric service is actually reduced where the wiring is properly installed. Precautions to be taken are to see that all wires are sufficiently large and properly insulated, the joints soldered and taped with rubber and friction tape, and all circuits provided with the proper size fuses. The wiring and equipment must also be installed so that the shock hazard is reduced to a minimum. It is generally known that farm animals are able to withstand but very slight electric shocks. In barns, hog houses, dairies, and other buildings where the humidity may be high, electric motors that are not properly grounded may become "alive" due to condensation on the motor windings resulting in an insulation leakage. Rigid metallic conduit may likewise become charged if proper drainage is not provided for. Open-type knife switches, altho somewhat cheaper than the enclosed types, are always a serious shock hazard and should not be used in any installation. Care should be taken to select wiring materials that will withstand dampness, ammonia fumes, and other corroding agencies in order to obtain as nearly as possible a "shock proof" wiring job.

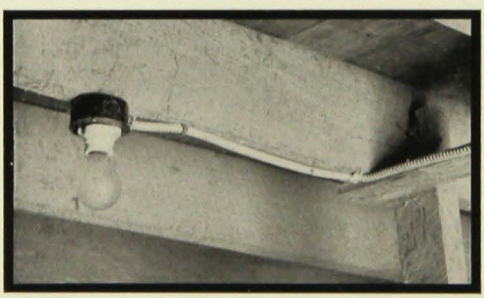


FIG. 5. ARMORED CABLE WIRING IN A GRANARY

When used in dry locations, this type of material offers excellent protection to the wires.

Farm wiring should be *adequate*. In wiring for electricity it is well to bear in mind that many of the lighting and power units which are being replaced are portable, whereas the electrical appliances must either be fixed or connected by a flexible cable to an electrical outlet. The proper number of, and locations for, the various lighting, power, and convenience outlets should be carefully considered when making the wiring plans. Wires should be of adequate size so as to allow only a minimum of voltage drop or dimming of lights when large appliances are turned on. The small saving that might be made by cutting down on wire sizes may be more than offset over a period of time by inefficient service. A voltage drop indicates that energy is being absorbed by the distribution system, which is recorded on the consumer's meter. With a reduced voltage the

time required to do a certain power or heating job is increased, meaning that more electrical energy is being consumed than with the proper voltage.

FARMSTEAD WIRING PLAN

Before contracting for the wiring job, the prospective user of electricity should make a list of electrical equipment to be used or which may be installed at some future time. A sketch of the farmstead drawn to scale will be of great help in locating the yard distribution system. On this sketch the number and size of the service wires to each building and the location of the transformer, yard lights, and power outlets should be designated. If only a part of the farm wiring can be installed at present, this should be of sufficient capacity to carry any reasonable future load without requiring replacement with larger wire. Care should be taken in placing the poles and wires so the job will not be an eyesore. The line of travel in doing chores after dark should be followed through to determine the location and the number of yard lights needed. Plan the electrical layout not as an added expense or luxury but as something to save time, labor, and expense in doing the daily work on the farm.

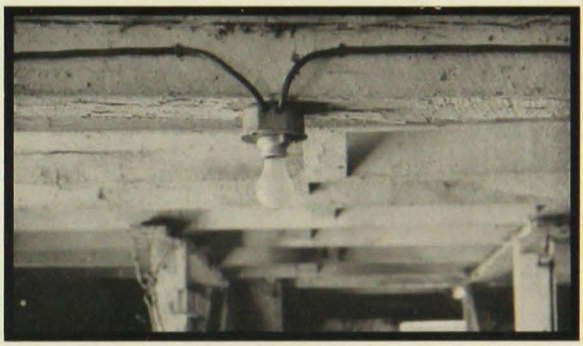


FIG. 6. NON-METALLIC SHEATHED CABLE INSTALLED IN A DAIRY BARN

The cable is attached directly to joists with special staples.

TRANSFORMER

Electricity from a power line is generated at some central station and transmitted over the rural distribution line at a high voltage (usually 2,300 or 6,900 volts). At the farm transformer the high voltage is changed to a lower voltage (110 and 220 volts) suitable for operating power and lighting loads. The high-voltage wires coming to the transformer from the line are known as the primary wires, and those going from the transformer to the load are known as the secondary wires.

Because of the lower line construction cost and lower line loss, single-phase alternating current is nearly always supplied to farm distribution lines.

The transformer should if possible be so located that power can be distributed with the least amount of voltage drop to the entire farmstead. This, however, may not always be possible as other things must be considered. For example, the transformer pole should not be located in the

farm yard where it can be used as a hitching post or where farm animals can rub against it. It should not be located where it can be interfered with by large farm machinery or metal pipes. A good location is along the farm entrance driveway.

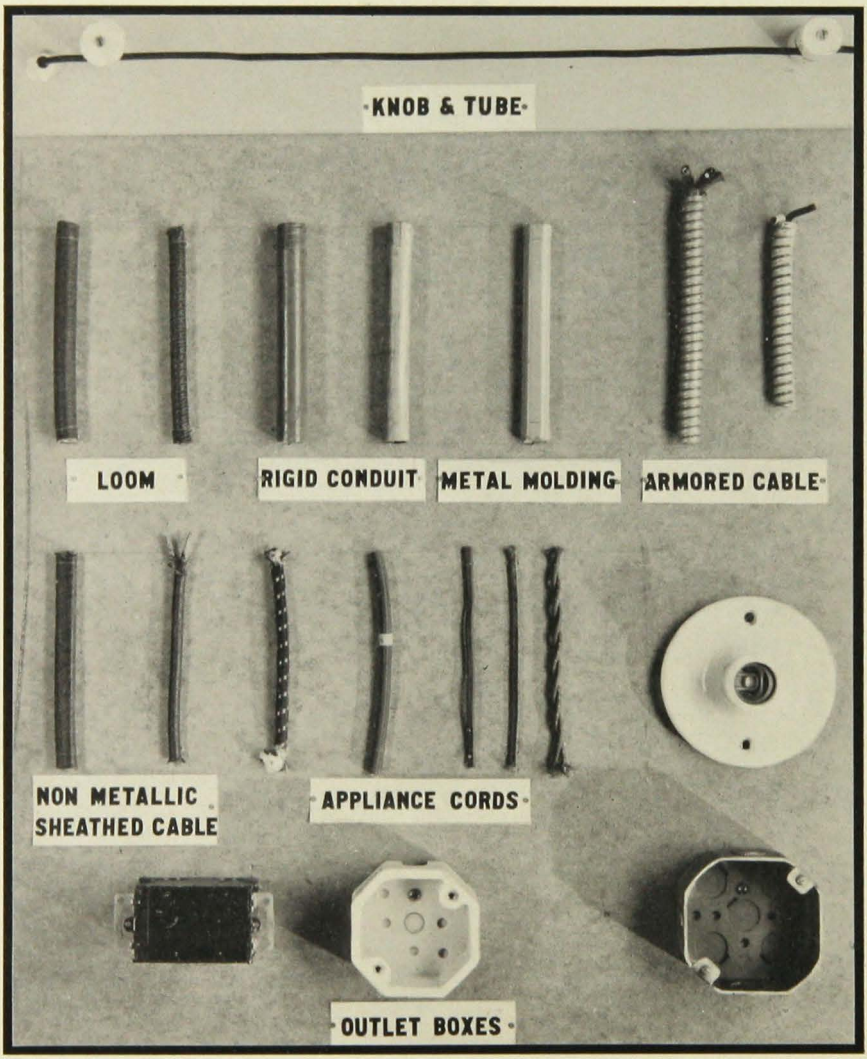


FIG. 7. COMMONLY USED WIRES AND WIRING MATERIALS

Knob and tube wiring is rubber-covered wire supported on porcelain knobs or run through porcelain tubes when passed through partitions or joists.

Loom is a weather-resistant fabric tube used to protect rubber-

covered wires in knob and tube wiring. It is used to protect wires from making contact with a wall, water pipe, or any part of the plumbing system.

Rigid conduit is available in two grades. Left: Standard or heavy weight. Right: Thin wall or light weight.

Metal moldings are used for service extensions in buildings where it is difficult to run wires through walls such as brick or masonry.

Armored cable consists of rubber-covered wires enclosed in a spirally wound sheath.

Non-metallic sheathed cable is made in two different types. The one at the left consists of two or three rubber-covered wires which are enclosed in a weather-resistant sheath. The one at the right consists of one or two rubber-covered wires surrounded by a bare stranded wire wound spirally around the other wire or wires. A layer of weatherproof paper and a fabric sheath are wrapped around and enclose the wires. This latter type often is referred to as C.N.X., a trade name. In using this type, care must be taken not to use the neutral or outside wire for the live or hot side of the line. Cases have been found where wiremen have used the center and the outside wire to and from a switch in order to save time and material. This is a dangerous practice as the neutral wire is not properly insulated for, nor intended for, use on the live side of the line.

Appliance cord. Left: Rubber, asbestos, and cotton-covered iron or toaster cord. Second: Rubber-covered duplex cord suitable for vacuum cleaners, refrigerators, washing machine, and other portable equipment. Third and fourth: Silk-covered duplex lamp cord. Fifth: Cotton-covered braided drop cord.

Outlet boxes are used for switches, convenience outlets, and lamp outlets with most types of wiring. When using rigid conduit, armored cable, and non-metallic sheathed cable, all joints and connections must be made in outlet boxes.

MAIN ENTRANCE SWITCH

The secondary or low-voltage wires are run from the transformer to the main entrance switch and meter. These switches are available in three sizes—30, 60, and 100 amperes. The minimum size to use for the farm is 60 amperes. If motors 5 H.P. and larger and an electric range are used, a 100-ampere switch must be used. The main entrance switch may be located in a building and should be near the load center. Oftentimes it is more convenient to run the wires to a pole on which may be located the yard light and an outdoor type of switch and meter. The advantage of an outdoor meter and switch is that it is always easily accessible, and in case of a fire in the farm buildings the service for pumping water may usually be continued without interruption. Three service wires are run to the main entrance switches and provide 110 volts for lighting and small motor operation and 220 volts for larger power purposes. One of the wires is known as the neutral or grounded wire which is connected to moist earth. The neutral and either one of the

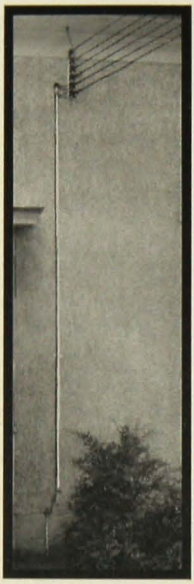


FIG. 8. A HOUSE SERVICE ENTRANCE

The three upper wires control the yard light from a three-way switch located in the kitchen. The three lower wires supply three-wire service to the house. The service wires are carried down the wall and into the basement through rigid conduit.

ungrounded wires supply 110 volts and the two ungrounded wires supply 220 volts.

In addition to the main entrance switch, separate entrance switches should be provided in each of the buildings. These switches contain one or more branch circuits from which the electricity is distributed to the various parts of the building.

In the house usually three or more branch circuits are required. In other buildings on the farm a single branch circuit switch is often sufficient for the lighting load, separately fused safety switches being used for all motors. All motors in excess of ⅓ H.P. should be wired for 220 volts to insure better starting conditions in cold weather and a minimum of voltage drop. The percentage of voltage drop in a line is four times as great when using a 110-volt motor or appliance as with 220 volts.

TYPES OF WIRING

KNOB AND TUBE or open wiring consists of rubber-covered wire supported by porcelain knobs or passed through porcelain tubes. For new houses and farm outbuildings this is the cheapest kind of wiring and is approved by the National Code. Recently a new type of porcelain outlet box has been designed which is especially suitable for use in damp places such as barns, hog houses, and basements. These boxes are made for use with knob and tube as well as for non-metallic sheathed cable wiring. When this type of box is used and all joints are properly soldered and taped, knob

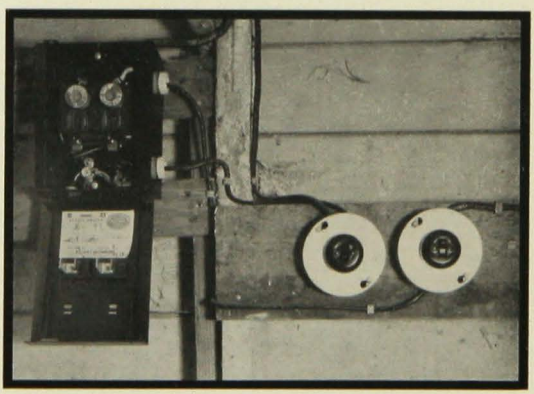


FIG. 9. ENTRANCE SWITCH AND SERVICE SWITCHES IN A DAIRY BARN

Left: Safety entrance switch in a dairy barn. The circuit is broken when the cover is opened as shown.

Right: Tumbler bakelite service switches, one to control the lights in the barn and the other a three-way switch to control the yard light.

and tube wiring is safer from the standpoint of shock hazard than the more expensive rigid or flexible metallic conduit. It does not give the neat appearance of a conduit job and should not be used where it is subject to mechanical strain as in the haymow of a barn.

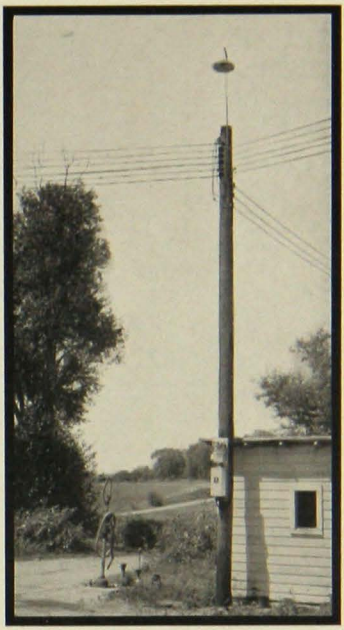


FIG. 10. SERVICE POLE WITH YARD LIGHT

Outdoor type of meter and switch is located on the service pole. The yard light is operated by two three-way switches located in the kitchen and in the barn.

FLEXIBLE METALLIC CABLE or armored cable is made up of either two or three standard rubber-covered wires covered with a thin metal sheath spirally wound about the wires. It is a very satisfactory type to use in houses or any dry location. It offers good protection to the wires and gives a neat-appearing wiring job. It is not recommended for barns, hog houses, dairies, and other damp locations as it lasts but a few years in such locations. The material cost is somewhat higher than for knob and tube, but the labor cost in wiring old houses or buildings where the wiring is to be concealed is considerably less. The total cost of wiring an old house where the wires must be fished through is about the same as for knob and tube.

RIGID CONDUIT is an iron pipe made especially for electrical wiring. The interior is made smooth and protected with enamel, and the exterior is either enameled or galvanized. The conduit is first fitted into the wall and then standard rubber-covered wires are pulled through to the various outlets. Some local ordinances require that all wiring in new buildings must be in rigid conduit. In barns, hog houses, dairies, etc., it has the same objections as flexible metallic conduit and is not recommended in these buildings except where mechanical protection is required such as in the haymow and for ground cable protection. All types of metal conduit should be securely fastened to the outlet boxes and the metal properly grounded.

NON-METALLIC SHEATHED CABLE is similar to armored cable except that it is enclosed in a moisture- and fire-resistant fabric sheath. Cable of this type is easily installed by fastening directly to the walls with staples or running it through holes bored through the partitions. The new type of porcelain outlet boxes are also available for this type of wiring. When used with non-corroding switches and receptacles it provides practically a shock-proof installation. Non-metallic sheathed cable wiring gives a neater appearing job than knob and tube and is easier to install in old buildings where the wires must be fished through partitions

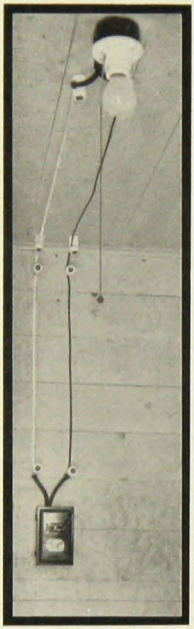


FIG. 11. KNOB AND TUBE WIRING IN A MILK HOUSE

The light is operated with a pull chain switch. Note the enclosed type entrance switch on the wall.

and between floors. The wiring is also better protected from mechanical injury in that the cable is nailed directly to the walls or joists.

In selecting this type of cable for use in the barn, dairy, etc., make sure that it is able to withstand moisture and other corroding agencies usually found in these buildings. Several types of non-metallic sheathed cable are available on the market, some of which are only suitable for residential jobs and other dry locations. According to the designers of the porcelain box, the cost of this type of wiring is about the same as BX and approximately 10 to 15 per cent higher than knob and tube.

WIRE SIZES

Electric wire sizes are rated according to the Brown and Sharpe (B & S) gauge, or American Wire Gauge (AWG). As will be seen from the table below, the size of the wire decreases as the number increases.

WIRE TABLE

Size	Diameter in inches	Resistance in ohms per 1,000 feet	Maximum capacity in Amperes (National code)	
			Rubber-covered	Water-proof
19	0.0400	6.3834	3	5
16	0.5008	4.0096	6	8
14	0.0604	2.5214	12	16
12	0.0719	1.5855	17	23
10	0.1019	0.9970	24	32
8	0.1285	0.6269	33	46
6	0.1620	0.3944	46	65
4	0.2043	0.2480	65	92
2	0.2576	0.1560	90	131
1	0.2893	0.1237	107	156
0	0.3249	0.9813	127	185

To use this table to determine the voltage drop in a line, assume a power outlet to be located 100 feet from the meter and a current of 40 amperes is flowing over No. 6 wires. The total length of line will be 2x100 feet or 200 feet. The resistance of 200 feet of No. 6 wire is .07888 ohm. The voltage drop is 40 amperes x .07888 ohm or 3.1562 volts. For motor operation the voltage drop should not exceed 5 per cent of no load voltage, and for lighting it should not exceed 3 per cent. For outside wiring, weather-proof insulated wires must be used. From the service entrance switch to the main farm buildings, such as the house

and barn, three wires should be used, none of which should be smaller than No. 6. For service to the other farm buildings two wires are usually sufficient. In order to give the proper mechanical strength to withstand sleet and wind these should be No. 10 or larger.

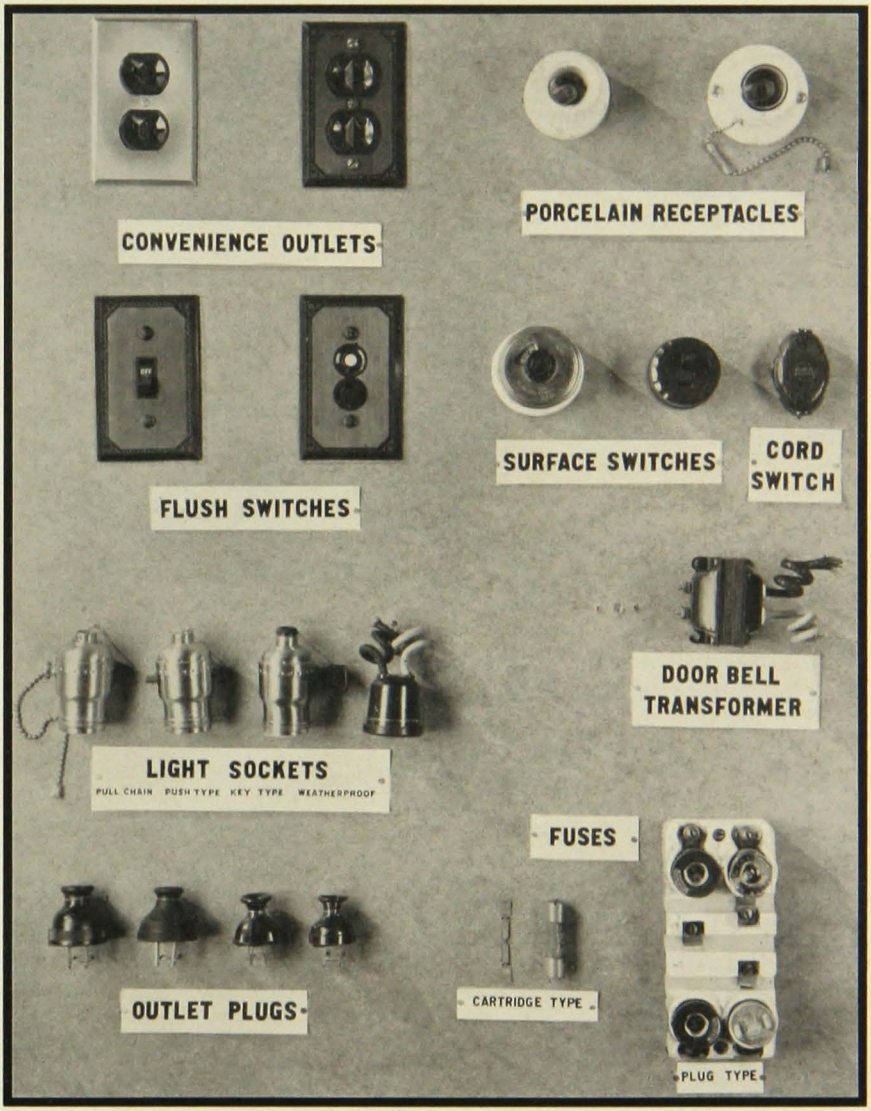


FIG. 12. APPROVED TYPES OF SWITCHES, RECEPTACLES, AND OTHER APPLIANCES USED IN WIRING

Convenience outlets. Duplex outlets enable one to connect in two appliances at the same outlet without the use of makeshift connections. The cost of duplex outlets is very little more than for single ones.

Porcelain receptacles should be used in basements, bathrooms, barns and other places where there is danger of condensation. The receptacle shown at the left is designed for use with knob and tube wiring and may be used without an outlet box. It is approved by the National Code but prohibited by some local codes. Receptacle at right is designed to fit over an outlet box.

Flush switches are made in two types—tumbler or toggle and push button.

Surface switches are mounted directly on the wall or on an outlet box. Many local ordinances require that all switches be used with outlet boxes.

Cord switches may be used on cords leading from a convenience outlet to portable equipment such as small motors or iron.

Light sockets are made in several types as shown. In basements, bathrooms, and farm outbuildings sockets should be of porcelain or some other weatherproof material.

Doorbell transformers are used to change a 110-volt current to a lower pressure, usually 8 volts, suitable for operating doorbells and other alarm systems.

Outlet plugs are made in several types. Note how the plug is shaped so as to facilitate removal from a receptacle.

Fuses are either of the cartridge type or the plug type. The strip at the left is the fuse link which is made of a low-melting-point alloy.

WIRING THE HOUSE

For all lighting loads and convenience outlets No. 14 wire is commonly used. With the tendency to increase the size and number of appliances used, many are finding it more satisfactory to use No. 12 wire for the convenience outlets as it provides a minimum dimming of lights when large appliances are turned on.

Convenience outlets should not be overlooked in planning the wiring job. With the increasing number of portable appliances, the wall outlets are usually used more than the ceiling ones. At least two convenience outlets should be provided in the living room, the dining room, and the kitchen, and one or more in each of the bedrooms.

The importance of providing lights in closets cannot be overemphasized. Trying to find one's way with a lighted match is not only inconvenient but constitutes a real fire hazard. A drop cord lamp located just inside of the closet door may be used. This may be operated either by a pull chain switch or a wall switch, the latter being located on the wall outside and on the knob side of the door.

For turning lights off and on from more than one point, such as the head and foot of stairs, three- and four-way switches should be used. Three-way switches control the lights from two points, and four-way switches operate from three points.

BARN WIRING

Barn wiring should be either knob and tube or non-metallic cable with rust- and corrosion-resistant boxes and porcelain receptacles. Wiring in the haymow should be enclosed in rigid metallic conduit to protect it against mechanical injury and against fire in case of a short circuit. The lights and all motors ⅓ H.P. and smaller are wired for 110 volts. All larger motors must be wired for 220 volts. The enclosed type of safety switch is recommended for all motors. Power companies recommend that in case of a pipeline milking machine, the connection between the pump and the line be made with a section of rubber hose to prevent the system from becoming alive in case of an insulation breakdown in the motor.

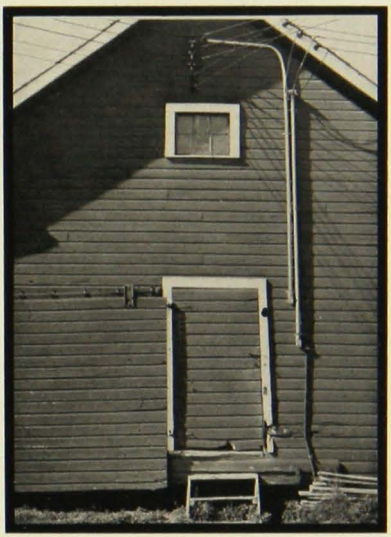


FIG. 13. MAIN SERVICE ENTRANCE SWITCH LOCATED IN THE GRANARY

Note how the rigid conduit has protected the ground wire which has been backed into with a piece of farm machinery breaking the siding.

POULTRY HOUSE

Many farmers find that night lighting of poultry houses is one of the best types of burglar insurance. Some poultrymen use artificial lighting to stimulate egg production. For this purpose, automatic time switches are available which may be used for dimming or to turn the lights on and off. Experiments at Cornell University show that a 40-watt lamp with a reflector placed six feet above the floor will illuminate a floor area of 200 square feet.

HOG HOUSE

Hog house wiring should be of the same type as is used in the barn. Since the humidity often reaches the saturation point, the same precautions should be taken as in wiring the barn.

In the shop, garage, machine shed, and other farm buildings where the interiors are usually dry, the main consideration is that of mechanical injury to the wires. Armored cable or rigid metallic conduit offer excellent protection. However, any of the other types of wiring may be used.

MOTORS

Most electrified farms are being equipped with 3 KVA transformers which will operate motors having the same number of horsepower. Since transformers can carry considerable overload, a 3 KVA transformer may

operate motors up to 5 H.P. This practice is not recommended, however, as it usually results in a high voltage drop and poor motor operation. Since electric motors can carry more than their rated horsepower, one often finds a 5 H.P. motor developing from 5-10 H.P., which means that if operated on a 3 KVA transformer the transformer may be overloaded more than 200 per cent. Where an electric range and 5 H.P. motor are used, a 5 KVA transformer must in all cases be installed. With the increase in the number of tractors on farms especially suitable for heavy belt work, many farmers are finding it more economical to use tractors for the belt power rather than duplicating with large electric motors.

In wiring for motors, care must be taken to use the proper size wires to obtain a minimum voltage drop. The starting current for motors is always much greater than the running current and may be up to 400 per cent of full load current. If large portable motors are used, special power outlets should be provided at the barn and other points where the motor may be used.

GROUNDING

The purpose of grounding is to protect against shock due to stray electric charges, high voltage caused by insulation leakage, and lightning discharges. To eliminate the possibility of electric shock from motors and other electrical appliances which may have become alive due to a breakdown in the insulation, all metal parts of the electrical system including metal conduit and metal outlet boxes must be connected to moist earth. The National Code permits the grounding to be done by connecting to the water system. In farm installations where the water system is often connected to drinking cups and water tanks in the barn, this practice may under conditions of a break in the water pipe line become dangerous. For this reason, separate ground rods should be provided which should be driven at least eight feet into earth.

In addition to grounding of the equipment, the neutral wire of the secondary system is also connected to earth. The purpose of this is to prevent a rise in voltage which may be caused by an insulation leakage or contact with the high-voltage system. For this, grounds are placed at the main entrance switch and at one or two other points such as at the house and barn service entrances. Another grounding of the neutral at the transformer pole is provided.

ELECTRICAL TERMS

Coulomb.—Electricity is often explained by comparing it to some common fluid such as water. The coulomb is the unit for measuring quantity of electricity and compares with the gallon or cubic foot which measures quantity of water.

Ampere.—A unit of current or rate of flow of electricity equal to one coulomb per second.

Ohm.—A unit of electrical resistance. The approximate resistance of 1,000 feet of No. 10 copper wire.

Volt.—A unit of electrical pressure. It is defined as the electrical

pressure required to cause a current of one ampere to flow through one ohm of resistance.

Watt.—A unit of power or the rate at which energy is expended or work done. A larger unit, the kilowatt, is equal to 1,000 watts. The power in watts is the product of volts and amperes. For example, a heater which draws 9 amperes on a 110-volt circuit has a power of 990 watts.

Kilowatt hour.—A unit of energy or work done. It is the product of power in kilowatts and time in hours. For example, a 40-watt lamp (.040 kw.) operated for 10 hours requires .040 kw. x 10 hours = 0.4 kw. hours of energy.

FIG. 14. A WELL ARRANGED FARMSTEAD WIRING LAYOUT
Note the location of the transformer. An outdoor type of metering cabinet is used.

Voltage drop or line drop.—The fall in electrical pressure along any conductor carrying an electric current. The value of the drop in volts is equal to the product of the current in amperes and the resistance in ohms.

Line loss.—The power loss in watts due to an electric current flowing through a conductor. It is the product of the current in amperes and the voltage drop in the line, or the amperes squared and the resistance of the line. For example, a line having a resistance of 2 ohms and carrying 10 amperes would have a line loss of 10^2 x 2 or 200 watts.

Direct current.—An electric current which flows in one direction only.

Alternating current.—An electric current which changes its direction

of flow at a regular rate. The number of complete changes or cycles is usually 60 per second.

Single phase.—A single alternating current is known as a single-phase A.C.

Three phase.—Practically all A.C. generators produce three single-phase alternating currents which differ from one another by 120 electrical degrees. Instead of requiring six wires for transmission, the three currents may be sent over three wires, thus cutting down on line costs. Three-phase current is not practical for farm lines as it requires three wires for distribution and two transformers at each farm.

K.V.A. (Kilovoltampere).—In alternating current circuits the amperes and volts may be out of step or phase. Under this condition the product of the voltmeter and ammeter readings does not correspond with the wattmeter reading. The product in this case is volt-amperes. The larger unit K.V.A. equals 1,000 volt amperes.

Fuse.—A ribbon or wire of low-melting-point alloy inserted in the wiring circuit as a protection against overloading or short-circuiting the system. Fuses are either of the plug or cartridge type.

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