## *Lesson 3: Wire Types and Uses*

The size and type of wire used for wiring are among the most important considerations in electrical installation. Different types of wire may be used, depending on the type of structure, its uses, and the electrical load of the circuits.

### Wire Types

Traditionally, electrical wire has been made from copper or aluminum. However, copper wire is the best conductor for most purposes. It is also the most widely used type of wire. Compared to copper, aluminum is a relatively poor conductor, and copper-clad aluminum is only slightly better. Aluminum wire must be two sizes bigger than copper wire would be to produce similar results.

Three categories of electrical wiring are typically used: service wires, interior wires, and cables. Service wires carry power into the home or building to the service entrance panel. The wires are either SE wires for overhead installations or USE wires for underground service. Service wires consist of a bundle of wires, with fine strands of uninsulated wire wrapped around the insulated wires, as shown in Figure 3.1. The uninsulated wire is the grounded neutral.

Interior wires, which are wires that must be protected from the elements, can be divided into two categories, Type T and Type R. Type T is The three categories of Type R wires are RH, RHH, and RHW. RH wire is designed for dry conditions and a maximum temperature of 167 degrees Fahrenheit. RHH is also designed for dry conditions but has a higher temperature rating of 194 degrees Fahrenheit. RHW wire will work in either wet or dry conditions and has a temperature rating of 167 degrees Fahrenheit.

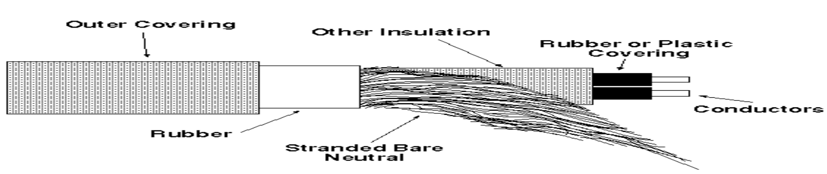
Cables form another category of electrical wire. To make a cable, individual wires are assembled and covered with a protective element. Cable is

the most commonly used interior wire type. This wire has thermoplastic insulation, which is a single layer of plastic compound that covers the individual wire. The insulation strips off easily and cleanly, making the wire easy to use. Type R wire was previously rubber coated for insulation, but advances in synthetic polymers have led to the use of these substances instead. This type of wire may also have a moisture-resistant, flame-retardant outer covering. Type R wires are rarely used in modern construction, although they are still found in many older structures.

Based on the wire's ability to withstand environmental and temperature conditions, Type T wires are divided into four categories: TW, THW, THHN, and THHW. TW wire is moisture resistant. However, the wire may not be buried directly in the ground. The insulation can withstand a maximum temperature of 140 degrees Fahrenheit. THW wire is considered to be both moisture and heat resistant. Its insulation has a heat rating of 194 degrees Fahrenheit. Like TW wire, it may not be buried in the ground. The insulation of THHN wire can also withstand a maximum temperature of 194 degrees Fahrenheit, but it may be used only under dry conditions. THHW wire, on the other hand, is designed for wet or dry conditions, with insulation that can handle a maximum temperature of 194 degrees Fahrenheit in dry conditions and 167 degrees Fahrenheit in wet conditions.

the predominant form of structural wiring used in the modern construction industry. The NEC has developed a set of identification requirements that indicate the information that must be present on the cable, as illustrated in Figure 3.2. This information includes the following elements.

- Size of the wires
- Insulation type
- Voltage rating
- Testing agency

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- Number of conductors
- Outer finish or covering

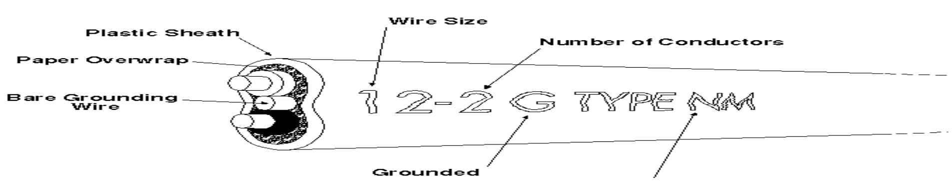
The three main types of cables are nonmetallic sheathed cable, armored cable, and flexible cord. Nonmetallic sheathed cable is the most common type of cable used in building construction. It typically contains two or three THHN or THHW wires with an additional bare ground wire. This cable is easy to install, clean in appearance, and highly economical. Nonmetallic sheathed cable comes in three forms: NM, NMC, and UF. NM is used in dry conditions and not in barns or other damp locations on agricultural operations. NMC is designed for damp or corrosive locations but cannot be buried underground. UF, or underground feeder, is identical to NMC but can be buried directly underground.

Another type of cable is armored cable. This cable is used in dry locations only. It normally contains TW, THW, or THHN wires. The individual wires are enclosed in a tough paper overwrap and spiral steel armor.

The third type of cable is flexible cord, which connects electrical devices to outlets. Various types of flexible cord are available. Types SPT-2 and S are used for connecting lamps, appliances, and other devices to outlets. Type SPT-2 has wires imbedded in plastic and is used for small appliances, such as lamps and radios. Type S is heavier and is used for applications where heavy use and abuse is possible, such as for power tools. The wires are bundled into a round assembly insulated with plastic or rubber. Another type of flexible cord is HPN, or heater cord. This type of cord is used with heating appliances, such as toasters and irons.

### Wires for Agricultural Wiring

Agricultural structures pose slightly different requirements than homes and businesses in terms of electrical work and wiring. Section 547 of the NEC describes the basic criteria. The NEC addresses two main categories of agricultural buildings. In the first category are buildings where excessive dust and dust with water may accumulate. Such buildings include totally enclosed and environmentally controlled poultry and livestock structures, confinement systems where litter, dust, and feed dust may accumulate, and feed mills. The second category consists of buildings with a corrosive atmosphere. These structures include totally enclosed and environmentally controlled areas where poultry and animal excrement may cause corrosive vapors in the confinement area, where corrosive particles may combine with water, or where the area is damp and wet because of periodic washing and sanitizing.

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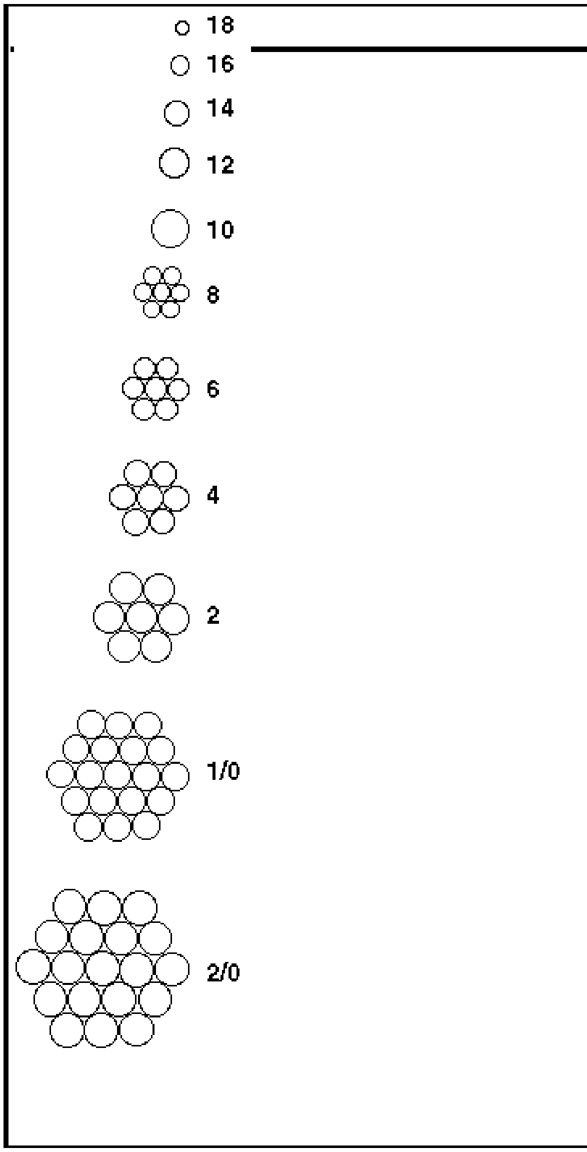



The types of wires approved for agricultural buildings are UF and NMC cables as well as other cables or raceways, which are enclosures like tubing that the cable runs through, that are highly resistant to corrosion. Both UF and NMC cables are approved for the two categories of structures, although UF cable is generally to be used underground; it can be used aboveground, but not in highly corrosive situations. The wires and fixtures in buildings with excessive dust must be "dust-ignition-proof" to protect against dust fires and explosions. Therefore, wires and fixtures should not produce arcs, sparks, or heat that is sufficient to cause the dust to ignite.

## The Importance of Wire Size

Wire size is measured using the American Wire Gauge (AWG), an industry-adopted scale that sets standard sizes. Smaller AWG numbers represent larger wire sizes. Number 14 wire is the smallest size allowed in most structures; however, in agricultural structures, the wire used should not be smaller than number 12 wire. Wire sizes range from 4/0, which is about ½ inch in diameter, to 20+. Figure 3.3 shows some common wire sizes.

One reason that wire size is an important consideration is ampacity. Ampacity, which is measured in amperes, is defined as the safe carrying capacity of the wire. The greater the amount of amperes flowing through the conductor, the greater the amount of heat produced. Doubling the amperes without changing the wire size will increase the heat output by four times. If the amperage is too high for a prolonged period, it may damage the insulation and lead to a fire.

Wire size is also important because of voltage drop. Voltage drop is the loss of electrical pressure over a length of wire. While some voltage drop is expected, and a 2 percent drop is acceptable, excessive voltage drop is wasted power. Machinery and equipment that run at lower than rated voltages work inefficiently. At 90 percent of its rated voltage, a motor produces only 81 percent of its normal power, and a lamp produces only 70 percent of its normal light output. Wire size affects voltage drop; a larger conductor provides a larger surface for more complete electrical flow. If more amperes are pushed through a conductor than its size allows, increased friction results, causing heat buildup and voltage drop.

## Selecting the Proper Wire Size

Some key information is needed before the appropriate wire size can be determined. The following information is required for calculating wire size: amperage load, voltage, wattage, and the length of run. The type of wire installation used, such as open air or buried wire, is also important, since larger wires are needed overhead for support and because of the voltage leak that occurs in these situations.

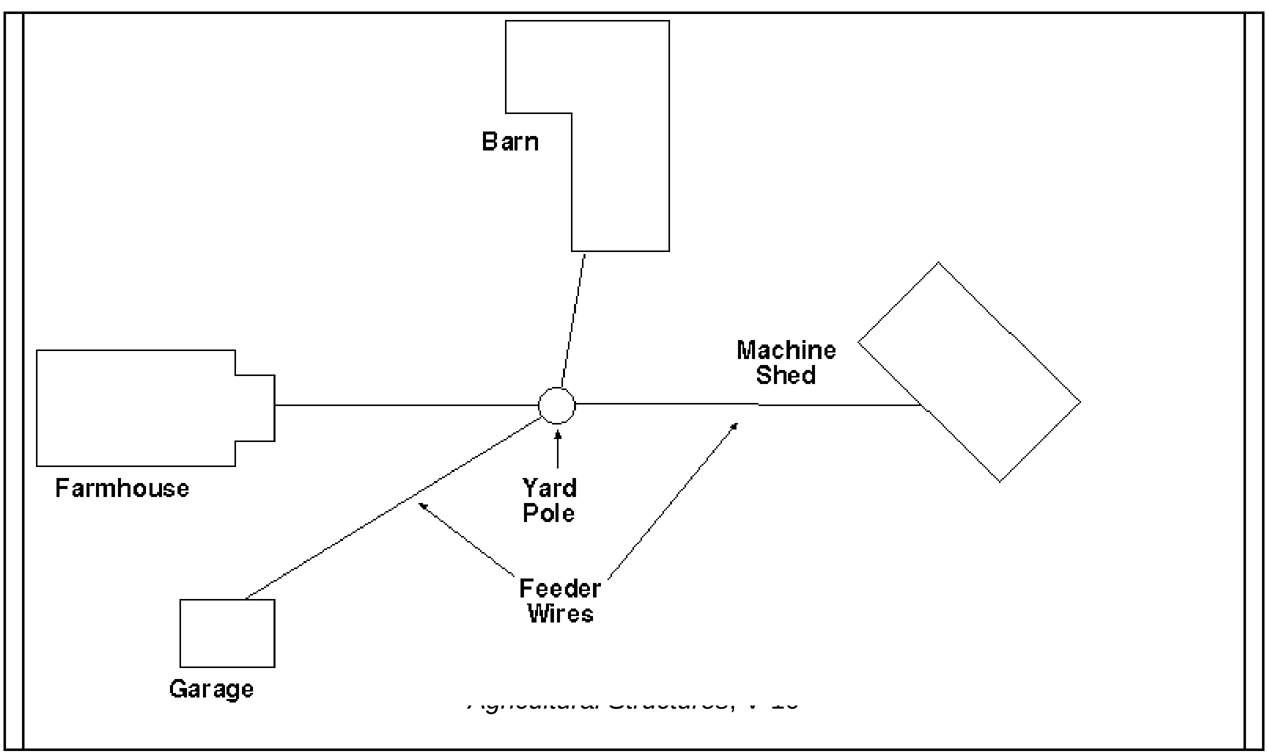
Using the information given in Table 3.1, wire size can be determined by using amperage, voltage, wattage, and the length of the run. Suppose that a wire carrying 30 amperes at 240 volts will run a one-way distance of 120 feet. Thirty amperes at this voltage is 7200 watts; to cross a distance of 120 feet requires a number 8 wire. When using the table given, always round up the calculated wattage in consideration of future growth and increased power conditions. If the distance the wire is to span falls between the distances given on the table, use the longer distance and the larger wire.

Use the section of the table describing the wire sizes needed for 240 volts whenever calculating the sizes of wires running into the service panel and to appliances and equipment that require 240 volts. A good strategy is to calculate the wire size as if it will be carrying 240 volts, because the wire can then be used for either 240 or 120 volts.

Beyond the basic considerations, overhead wires pose other requirements. The wires need to be large enough to support themselves without sagging and to maintain some rigidity under heavy snow loads. To carry 600 volts or less, AWG 10 is recommended for spans up to 50 feet in length. Number 8 wire is needed for longer spans. To carry over 600 volts, AWG 6 is needed where individual conductors are used, and number 8 where conductors form a cable. For all wiring distances over 150 feet, a second pole is recommended.

### Feeder Wires

Electrical power is brought to the farm by a power company. The service drop from the power company ends at a centrally located yard pole rather than a building. Feeder wires span the distance from the electrical service equipment at the pole to the service panel at each individual structure, as illustrated in Figure 3.4. They are either SE or USE wire, depending upon whether the service will be installed overhead or underground.



| One-Way Distances (in Feet) at 120 Volts, Single-Phase, with 2% Voltage Drop | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AWG Wire Sizes | | | | | | | | | |
| Amps | Watts | 14 | 12 | 10 | 8 | 6 | 4 | 2 | 1/0 | 2/0 | 3/0 |
| 5 | 600 | 90 | 140 | 225 | 360 | 570 | 910 | | | | |
| 10 | 1200 | 45 | 70 | 115 | 180 | 285 | 455 | 725 | | | |
| 15 | 1800 | 30 | 45 | 70 | 120 | 190 | 300 | 480 | 765 | 960 | |
| 20 | 2400 | 20 | 35 | 55 | 90 | 145 | 225 | 360 | 575 | 725 | 915 |
| 25 | 3000 | 18 | 28 | 45 | 70 | 115 | 180 | 290 | 460 | 580 | 730 |
| 30 | 3600 | 15 | 24 | 35 | 60 | 95 | 150 | 240 | 385 | 485 | 610 |
| 40 | 4800 | | | 28 | 45 | 70 | 115 | 180 | 290 | 360 | 455 |
| 50 | 6000 | | | 23 | 36 | 55 | 90 | 145 | 230 | 290 | 365 |

| One-Way Distances (in Feet) at 240 Volts, Single-Phase, with 2% Voltage Drop | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AWG Wire Sizes | | | | | | | | | |
| Amps | Watts | 14 | 12 | 10 | 8 | 6 | 4 | 2 | 1/0 | 2/0 | 3/0 |
| 5 | 1200 | 180 | 285 | 455 | 720 | 1145 | | | | | |
| 10 | 2400 | 90 | 140 | 225 | 360 | 570 | 910 | 1445 | | | |
| 15 | 3600 | 60 | 95 | 150 | 240 | 380 | 610 | 970 | 1530 | | |
| 20 | 4800 | 45 | 70 | 115 | 180 | 285 | 455 | 725 | 1150 | 1450 | |
| 25 | 6000 | 35 | 55 | 90 | 140 | 230 | 365 | 580 | 920 | 1160 | 1450 |
| 30 | 7200 | 30 | 48 | 75 | 120 | 190 | 300 | 480 | 770 | 970 | 1220 |
| 40 | 9600 | | 36 | 56 | 90 | 140 | 230 | 360 | 575 | 725 | 915 |
| 50 | 12000 | | | 45 | 70 | 115 | 185 | 285 | 460 | 580 | 725 |
| 60 | 14400 | | | | 60 | 95 | 150 | 240 | 385 | 485 | 610 |
| 70 | 16800 | | | | 50 | 80 | 130 | 205 | 330 | 410 | 520 |
| 80 | 19200 | | | | | 70 | 115 | 180 | 285 | 360 | 460 |
| 90 | 21000 | | | | | 60 | 100 | 160 | 260 | 320 | 405 |
| 100 | 24000 | | | | | 55 | 90 | 145 | 230 | 290 | 365 |
| 125 | 30000 | | | | | | 75 | 120 | 190 | 240 | 300 |
| 150 | 36000 | | | | | | | 95 | 150 | 195 | 245 |
| 200 | 48000 | | | | | | | 70 | 115 | 145 | 185 |

### Feeder Wires and Demand Load

The size of the feeder wire depends on the demand load for a structure. The demand load of an agricultural structure is typically considered to be the amount of power that will likely be needed at any given time. Normally, the minimal calculated demand load is about 35 percent of the total connected load, which is the maximum amount of power that would be drawn if all circuits and appliances were in use. A demand load factor of 35 percent (.35) suggests that only 35 percent of the electrical system will be active at a given time. However, depending upon the type and use of the electrical system within the structure, this percentage may be higher. The approximate amperage that will be in use will determine the necessary feeder wire size.

### Feeder Wire Size, Length, and Voltage Drop

The length of the wire plays a major part in determining the size of the feeder wire. Because length tends to be a fixed factor once the yard pole is in place, the size of the feeder wire must then be increased to avoid voltage drop if demand loads or amperage requirements increase. A good rule of thumb is to place the pole or power source as close as possible to the building or buildings that will have the highest electrical use, which will reduce the costs associated with buying larger wire sizes as well as the effects of voltage drop. It is important to note that the wire distances given in Table 3.1 are based on a 2 percent voltage drop. If a higher voltage drop is acceptable, the length can be increased. For example, for a 4 percent voltage drop, double the distance shown on the table for each wire size.

### Circuit Needs of a Structure

Several rules of thumb may be applied when calculating the circuit needs of a structure, although the codes required for buildings may vary by county and type of structure. For example, at least one lighting and/or convenience outlet is required for every 150 square feet of floor space. Each square foot of floor space should have a minimum of 3 watts of lighting; most structures will require more. Convenience outlets should be installed every 12 feet along walls.

Various circuit sizes are recommended for branch circuits, which are separate electrical paths that extend from the service entrance panel and have their own overcurrent protection devices. For 500 square feet of floor space, a branch circuit with a 20-amp minimum is necessary, while a 15-amp branch circuit is the minimum needed for every 375 square feet of floor space. A water heater requires a branch circuit of 30 amps, carrying 220 volts. A ventilation fan calls for a branch circuit of 20 amps, carrying 110 volts. Both a water pump and workshop bench should have a branch circuit of 20 amps, carrying 110 or 220 volts.

### Calculating Load

To calculate the load of an agricultural building, complete the following steps. An example is given to show how the steps are applied. The same process can be used to calculate the total load and demand load of branch circuits.

- List the number of circuits, special appliances, motors, etc. to be used.
- Determine the total volt-amperes (VA), or watts (W), for each by multiplying their amperage and voltage requirements; then multiply each one by the number of power outlets of that type.
- Add the numbers to determine total wattage of the structure.
- Multiply by the demand load factor. If in doubt about the size of the demand load, use a higher percentage to take into account future growth and the maximum electrical use at a given time.

Suppose that a structure has ten lighting circuits, five outlets, three motors, and a heater all at 240 volts. The distance from the yard pole to the building is 100 feet. The demand load factor will be 50 percent. What would the demand load be?

Circuits and appliances:

10 lighting circuits, generally calculated at 400 W
5 outlets, generally calculated at 200 W

3 motors, at 1200 W, 2000 W, and 3000 W
1 heater, stamped with a rating of 5000 W

W requirements:

(1200 W + 2000 W + 3000 W) × 0.50 = 3100 W (Use .5 as a multiplier if all the motors do not run at the same time.)
Heater = 5000 W

Total W: 4000 W + 1000 W + 3100 W + 5000 W = 13,100 W or 13.1 kW

Demand load: 13.1 kW × 0.50 = 6.55 kW, or 6550 watts

Once the demand load has been calculated, the proper feeder wire size can be chosen. For example, in the problem given here, the wire size must be AWG 8 to carry the wattage and span 100 feet. When determining the wire size needed from the meter base, which is the socket where the electric meter is attached at the yard pole, to the point where the wires break down to the individual structures, the same procedure is used by calculating the total connected load for all buildings and then using the table to determine wire size. Always increase service conductors by one size in consideration of future growth and increased power load.

10 × 400 W = 4000 W
5 × 200 W = 1000 W

## Summary

The type and size of the wire used is critical to proper electrical installation. The wire, or conductor, directs the electrical current throughout the system, and these conductors must be of ample size to efficiently conduct the current. It is important to be able to calculate electrical usage and then use this information to determine wire size, while taking into account future demands and expansion.

## Credits

Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Richter, H.P., and W.C. Schwann. *Wiring Simplified*. 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.