UNIT V - ELECTRICITY

Lesson 3: Wire Types and Uses

Competency/Objective: Match types and sizes of wire with their uses.

Study Questions

1. What are the different types of wire?
2. Which wires are best adapted for agricultural wiring?
3. Why is wire size important?
4. How is the right wire size selected?
5. What are feeder wires?
6. How does demand load affect the feeder wire?
7. How does length and voltage drop affect feeder wire size?
8. What are some rules of thumb to apply when calculating the circuit needs of a structure?
9. What is the procedure for calculating the load in an agricultural building?

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
    a) TM 3.1: Service Wire
    b) TM 3.2: Cable
    c) TM 3.3: Wire Sizes
    d) TM 3.4: Wiring Tables
    e) TM 3.5: Feeder Wires
3. Activity Sheet
    a) AS 3.1: Calculating Feeder Wire Size

UNIT V - ELECTRICITY

Lesson 3: Wire Types and Uses

TEACHING PROCEDURES

B. ***Review***

In the previous lesson, the importance of safety when working with electricity and electrical terminology were stressed. This information will now be applied to actual wiring procedures. When planning electrical systems in construction, determining the types of wires to be used is a priority. To choose the proper type of wire and wire size, it is important to be familiar with the types of wire available and the uses of each, the NEC recommendations for agriculture structures, and the electrical load to be placed on the wire.

C. ***Motivation***

1. Buy different sizes of tubing (_", ¼", ½", ¾") from a hardware store and bring them to class. Have students answer the following questions.

   - Which tube will allow the least amount of water through?
   - Which will allow the greatest?
   - What will happen if the same amount of water carried through the ¾" tube is forced through the ¼" tube? (Increased pressure!)
   - What does this pressure create? (Friction)

2. The same principles apply to electricity and electrical wiring. Think of the tubing as the wire and the water as electricity. Just like the tubing, the goal when selecting electrical wire is to have the appropriate size to allow the needed amount of electricity to flow through it without experiencing losses in power, or voltage drop, due to excess friction throughout the path, which causes resistance to electrical flow.

D. ***Assignment***

E. ***Supervised Study***

F. ***Discussion***

1. For a building or structure to receive electricity, power must flow through a series of different sizes and types of wire. Each type of wire is identifiable by its components and a lettering scheme. Ask the class why it is important to have different types of wires available for conducting electricity. TMs 3.1 and 3.2 can be used to illustrate cables and emphasize the different components.

   What are the different types of wire?

a) Wire material
    1) Copper wire
        (a) Best conductor for most purposes
        (b) Most widely used
    2) Aluminum wire
        (a) Relatively poor conductor
        (b) Copper clad aluminum slightly better
        (c) Must be two sizes bigger than copper wire to produce similar results
b) Service wires - carry power into the home or building to the service entrance panel
    1) SE - overhead installations
    2) USE - underground service
    3) Consist of a bundle of wires, with fine strands of uninsulated wire wrapped around the insulated wires; the uninsulated wire is the grounded neutral
c) Interior wires - must be protected from the elements
    1) Type T
        (a) Most commonly used interior wire type
        (b) Has thermoplastic insulation, which is a single layer of plastic compound that covers the individual wire
        (c) Can strip insulation off easily and cleanly, making the wire easy to use
        (d) Divided into four categories based on the wire's ability to withstand environmental and temperature conditions
            (1) TW - moisture resistant; may not be buried directly in the ground; maximum temperature of 140 degrees Fahrenheit
            (2) THW - moisture and heat resistant, with a heat rating of 194 degrees Fahrenheit; may not be buried in the ground
            (3) THHN - dry conditions; maximum temperature of 194 degrees Fahrenheit
            (4) THHW - wet and dry conditions; maximum temperature of 194 degrees Fahrenheit in dry conditions and 167 degrees Fahrenheit in wet conditions
    2) Type R
        (a) Previously rubber coated for insulation but now uses synthetic polymers
        (b) May have moisture-resistant, flame-retardant outer covering
        (c) Rarely used in modern construction, although still found in older structures
        (d) Has three categories of wire
            (1) RH - dry conditions; maximum temperature of 167 degrees Fahrenheit
            (2) RHH - dry conditions; temperature rating of 194 degrees Fahrenheit

(3) RHW - wet or dry conditions; temperature rating of 167 degrees Fahrenheit

d) Cables - individual wires assembled and covered with a protective element; predominant form of structural wiring used in the modern construction industry
   1) Nonmetallic sheathed cable
      (a) Most common type of cable used in building construction
      (b) Contains two or three THHN or THHW wires with an additional bare ground wire
      (c) Easy to install, clean in appearance, and highly economical
      (d) Comes in three forms
         (1) NM - used in dry conditions, not in barns or other damp locations on agricultural operations
         (2) NMC - designed for damp or corrosive locations but cannot be buried underground
         (3) UF - identical to NMC but can be buried directly underground
   2) Armored cable
      (a) Used in dry locations only
      (b) Contains TW, THW, or THHN wires
      (c) Wires enclosed in tough paper overwrap and spiral steel armor
   3) Flexible cord
      (a) Type SPT-2
         (1) Wires imbedded in plastic
         (2) Used for small appliances, such as floor lamps, radios, etc.
      (b) Type S
         (1) Heavier
         (2) Used for applications where heavy use and abuse is possible, such as for power tools
         (3) Wires bundled into a round assembly insulated with plastic or rubber
      (c) Type HPN
         (1) Heater cord
         (2) Used for heating appliances, such as toasters and irons

2. Agriculture structures pose slightly different requirements than homes or businesses in terms of electrical work. Why?

Which wires are best adapted for agricultural wiring?

a) NEC categories of agricultural buildings
   1) Buildings where excessive dust and dust with water may accumulate
      (a) Totally enclosed and environmentally controlled poultry and livestock structures
      (b) Confinement systems where litter, dust, and feed dust may accumulate
      (c) Feed mills

2) Buildings where a corrosive atmosphere exists - totally enclosed and environmentally controlled areas where:
   (a) Poultry and animal excrement may cause corrosive vapors in the confinement area
   (b) Corrosive particles may combine with water
   (c) The area is damp and wet because of periodic washing and sanitizing with water and cleansing agents, as is the case in milk parlors

b) Approved wires for agricultural buildings
   1) UF, NMC, and other cables or raceways that are highly resistant to corrosion
   2) In buildings with excessive dust, must have “dust-ignition-proof” wires and fixtures that do not produce a

rcs, sparks, or heat sufficient to cause dust to

i
g
n
i
t
e

3. The size of the wire is as important as selecting the proper wire type for a job. Ask students why wire size matters. Refer back to the demonstration of the tubes in the motivation section. Show students TM 3.2 to illustrate wire size.

Why is wire size important?

a) Wire size is measured using the American Wire Gauge (AWG).
   1) Smaller AWG numbers represent larger wire sizes.
   2) Number 14 is the smallest size allowed in most structures, although the wire size used in agricultural structures should not be smaller than number 12.
   3) Wire sizes range from 4/0 (about ½ inch in diameter) to 20+.

b) Wire size is important for two reasons.
   1) Ampacity is defined as the safe carrying capacity of the wire.
      (a) The greater the amount of amperes flowing through a conductor, the greater the amount of heat produced.
      (b) Doubling the amperes without changing the wire size will increase heat output by four times.
      (c) If the amperage becomes too high for a prolonged period, it may damage the insulation and start a fire.
   2) Voltage drop is the loss of electrical pressure over a length of wire.
      (a) Some voltage drop is expected, and a 2 percent drop is acceptable, but excessive voltage drop is wasted power.
      (b) Machinery and equipment that run at lower than rated voltages work inefficiently.
      (c) Wire size affects voltage drop; a larger conductor provides a larger surface for more complete electrical flow.
      (d) If more amperes are pushed through a conductor than its size allows, increased friction results, causing heat buildup and voltage drop.

4. After electrical loads are established for each circuit, the proper wire size must be determined. Discuss how to select the proper wire size. Show the students the table on TM 3.3 and explain its use.

How is the right wire size selected?

a) Some key information is needed before the appropriate wire size can be determined.
   1) Amperage load
   2) Voltage
   3) Wattage
   4) Length of run
   5) Type of wire installation used, such as open air or buried wire, since larger wires are needed overhead for support and because of voltage leaks

b) Wire size can be determined by using amperage, voltage, wattage, and the length of the run.

   NOTE: Show the class the tables on TM 3.3 and explain how they are used to choose a wire size for a particular situation. As an example, use 30 amperes at 240 volts with a one-way distance of 120 feet, requiring a number 8 wire. Explain that different tables would be used with underground wires.

   1) Always round up calculated wattage in consideration of future growth and increased power conditions.
   2) If the distance the wire is to span falls between the distances given on the table, use the longer distance and the larger wire.

c) Beyond the basic considerations, overhead wires pose other requirements.
   1) The wires need to be large enough to support themselves without sagging and to maintain some rigidity under heavy snow loads.
   2) 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.
   3) To carry over 600 volts, AWG 6 is needed where individual conductors are used, and number 8 where conductors are in the form of a cable.

5. For agricultural facilities, power is brought in and distributed differently than in most homes and businesses. Ask students to explain the differences. Show students TM 3.4 to illustrate power distribution from a yard pole through feeder wires.

   What are feeder wires?

   a) The feeder wires span the distance from the electrical service equipment at the pole to the service panel at each individual structure.
   b) They are either SE or USE wire, depending upon whether the service will be installed overhead or underground.

6. When planning to supply electrical power to outlying agriculture structures, the demand load of those structures needs to be taken into account. Ask the class to define demand load. What is the connection between demand load and feeder wire size?

   How does demand load affect the feeder wire?

a) The size of the feeder wire depends on the demand load for a structure.
b) Demand load is considered to be the amount of power that will likely be needed at any given time.
c) The minimal calculated demand load is normally about 35 percent of the actual connected load.
d) Depending on the type and use of the electrical system within an agriculture structure, this percentage may be higher.
e) The approximate amperage that will be in use will determine the necessary feeder wire size.

7. Discuss the effect of wire length and voltage drop on feeder size. Have students complete AS 3.1.

How does length and voltage drop affect feeder wire size?

a) 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.
b) 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.

8. Discuss the guidelines that should be applied when planning the circuit requirements of a structure.

What are some rules of thumb to apply when calculating the circuit needs of a structure?

a) Lighting and/or convenience outlets - at least one for every 150 square feet of floor space
b) Minimum of 3 watts of lighting for each square foot of floor space
c) Convenience outlets installed every 12 linear feet along walls
d) Branch circuit with a 20-amp minimum for 500 square feet of floor space
e) Minimum of a 15-amp branch circuit for every 375 square feet of floor space
f) Water heater - branch circuit of 30 amps, carrying 220 volts
g) Fan - branch circuit of 20 amps, carrying 110 volts
h) Water pump - branch circuit of 20 amps, carrying 110 or 220 volts
i) Workshop bench - branch circuit of 20 amps, carrying 110 or 220 volts

9. Ask students what they would do to calculate the electrical load for a building. Explain the steps of the procedure for calculating load.

What is the procedure for calculating the load in an agricultural building?

a) List the number of circuits, special appliances, motors, etc. to be used.

b) Determine the total volt-amperes (VA), or watts (W), for each by multiplying their amperage and voltage requirements and then multiply each one by the number of power outlets of that type.
c) Add the numbers to determine total wattage of the structure.
d) Multiply by the demand load factor; if in doubt about the size of the demand load, use a higher percentage.

EXAMPLE: Use this example to demonstrate how to calculate feeder wire size. The problem given is also included in the *Agricultural Structures* student reference.

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:

10×400 W = 4000 W
5×200 W = 1000 W
(1200 W + 2000 W + 3000 W) $\times$ 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 $\times$ 0.50 = 6.55 kW, or 6550 watts

G. *Other Activities*

Using the classroom or shop, have the students determine the number and electrical requirements of lights, outlets, and equipment. Use this information to determine the volt-ampere/watt requirements of the area and the size of the feeder wire needed to connect the meter base to the service panel.

H. *Conclusion*

Choosing the correct wire type for agricultural structures is important, since certain hazards may be present if inappropriate wires are used. The size of these wires is also critical, since the electrical system may operate inefficiently if conductors are not large enough. Feeder wires are especially important, since they carry electricity from the service equipment at the yard pole to the individual structures of the farmstead. Determining the correct feeder wire size involves calculating the amount of electrical usage and the demand load of the structure.

I. ***Answers to Activity Sheet***

1. TOTAL CONNECTED LOAD = 29500 W
2. DEMAND LOAD = 29500 W × .45 = 13275 W
3. WIRE SIZE = No. 6 AWG

J. ***Answers to Evaluation***

1. d
2. c
3. e
4. a
5. b
6. b
7. c
8. a
9. Amperage load, voltage, wattage, length of run, and type of wire installation used
10. NMC and UF
11. Ampacity and voltage drop

12. List the number of circuits, special appliances, motors, etc. to be used.

13. Place the yard pole as close as possible to the building or buildings that will have the highest electrical use to reduce wire costs and the effects of voltage drop.

14. Demand load is typically considered to be the amount of power which will likely be needed at any given time.

Lesson 3: Wire Types and Uses Date _____

EVALUATION

Match the term on the right with the description on the left.

1. ____	Heater cord	a. THW
2. ____	Nonmetallic cable; corrosive areas	b. RH
3. ____	Underground service cables	c. NMC
4. ____	Heat and moisture resistant	d. HPN
5. ____	Dry conditions	e. USE

Circle the letter that corresponds to the best answer.

6. For 500 square feet of floor space, a minimum _____ branch circuit is required.

   a. 15-amp
   b. 20-amp
   c. 25-amp
   d. 30-amp

7. The wires that span the distance from the electrical service equipment at the pole to the service panel at each individual structure are:

   a. Cords.
   b. Demand cables.
   c. Feeder wires.
   d. Copper wires.

8. What is the minimum wattage for lighting per square foot of floor space?

   a. 3
   b. 4
   c. 5
   d. 6

Complete the following short answer questions.

9. What are the five pieces of information required to determine the wire size?

a.

b.

c.

d.

e.

10. What are two examples of approved wires for agricultural buildings?

    a.

    b.

11. What are two reasons that using the proper wire size is important?

    a.

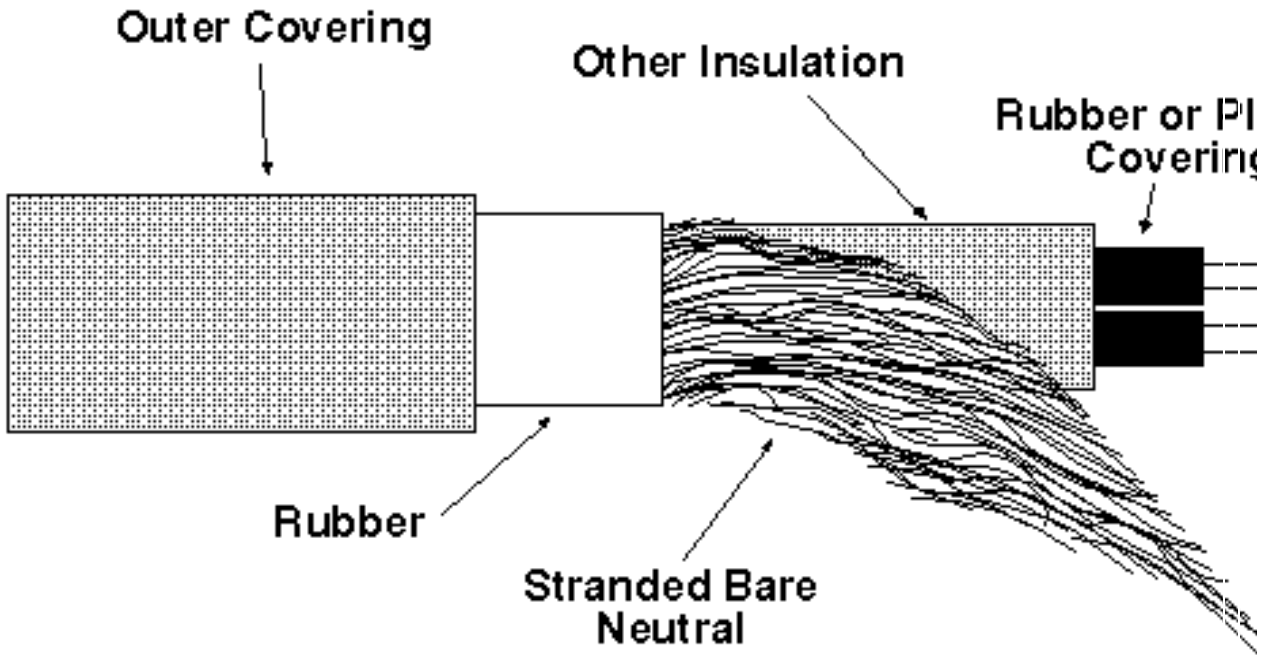
    b.

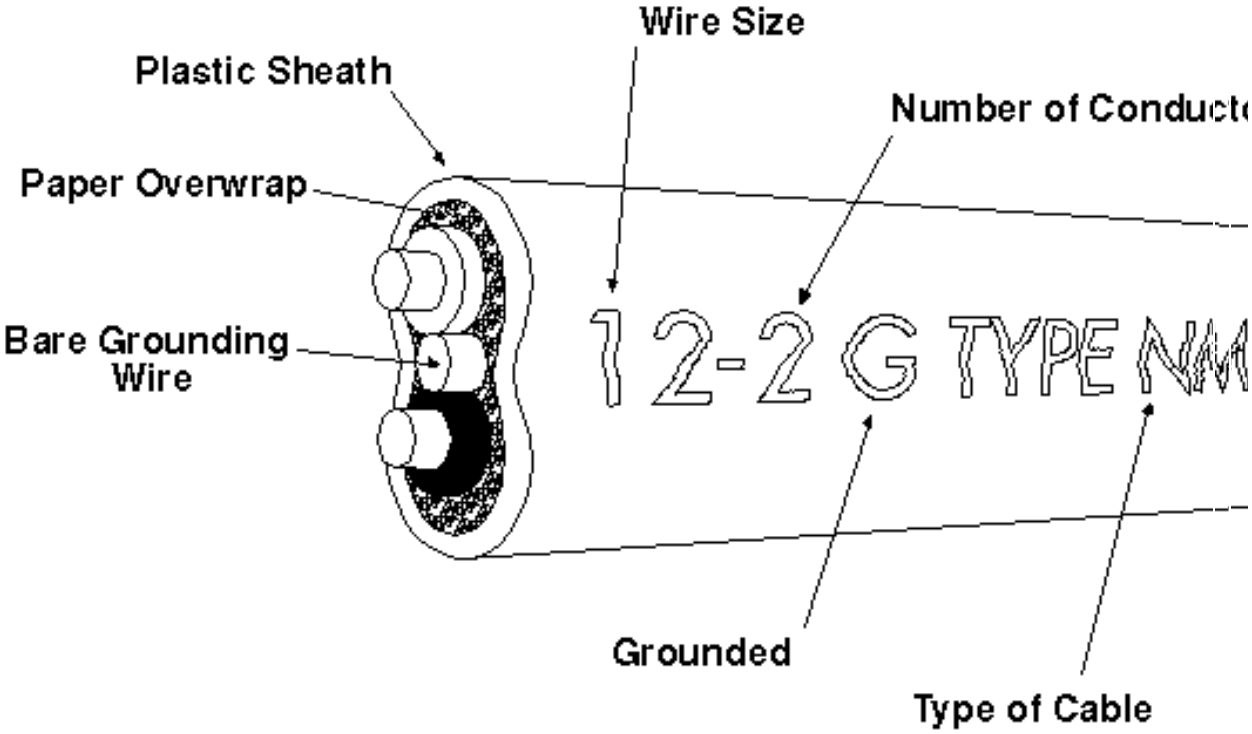
12. What is the first step in calculating load for an agricultural structure?

13. Where would the electrical service pole best be located, and why?

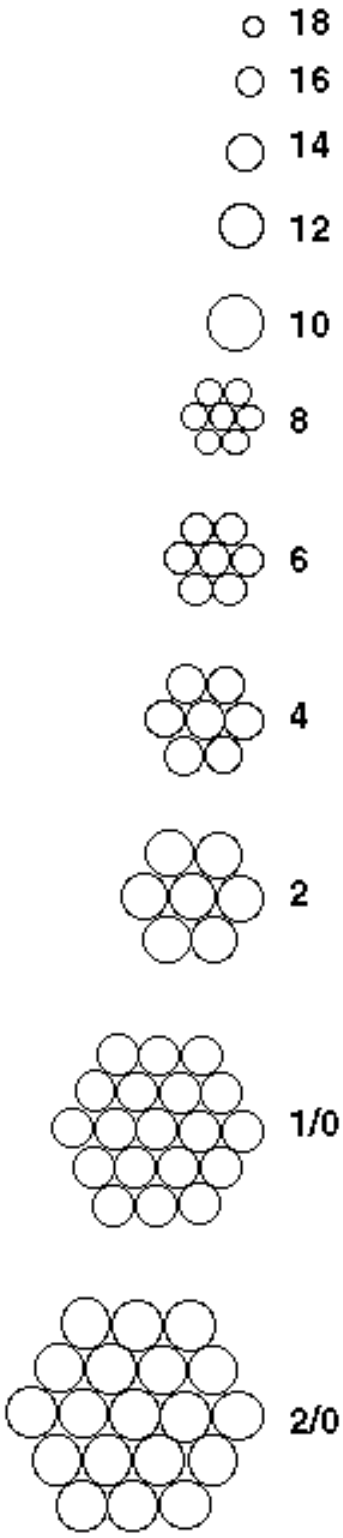
14. What is demand load?

Service Wire


Outer Covering
Other Insulation
Rubber or Pl
Coverin
Rubber
Stranded Bare
Neutral


Wire Size
Plastic Sheath
Number of Conduct
Paper Overwrap
Bare Grounding Wire
12-2 G TYPE NM
Grounded
Type of Cable

Wire Sizes

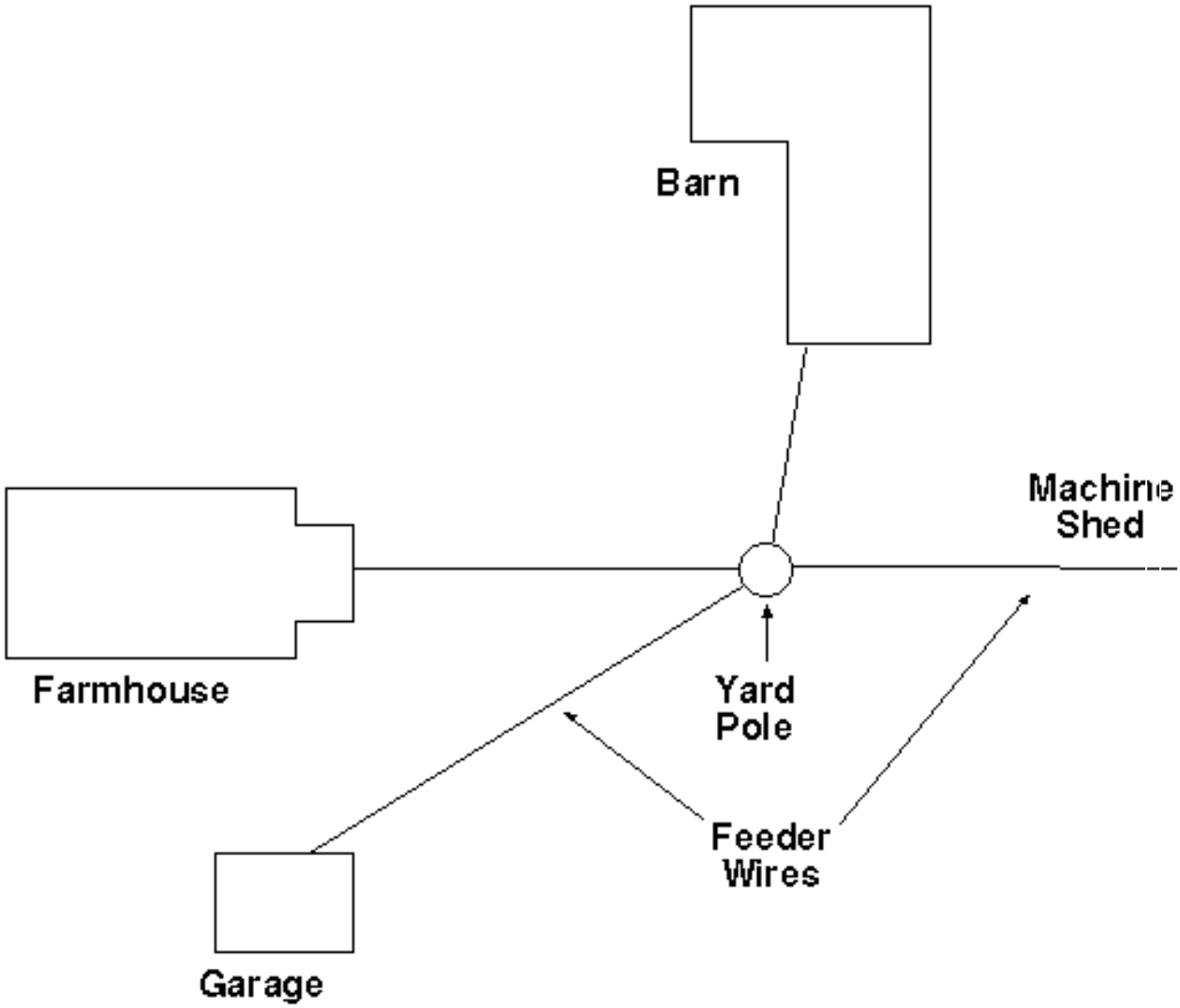


Wiring Tables

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


Barn
Machine Shed
Farmhouse
Yard Pole
Feeder Wires
Garage

Lesson 3: Wire Types and Uses Name _____

Calculating Feeder Wire Size

Objective: Calculate the total connected load, the demand load, and the feeder wire size.

Using the information provided and the necessary tables from the student reference, calculate the total connected load, the demand load, and the AWG wire size for the feeder wire. Show your work.

Circuits and appliances at 240 volts:

15 lighting circuits at 400 W each
12 receptacle outlets at 200 W each
5 motors, ½, 1, 2, 2, and 4 hp
1 heater at 7000 W
2 ventilation fans at 4500 W each

Motor data:

½ hp	500 W
1 hp	1200 W
2 hp	2000 W
4 hp	4500 W

Other information:

Use 0.50 factor for electrical motors.
Use a demand load factor of 45%.
The length of the run from service pole to service panel is 75 feet.

1. TOTAL CONNECTED LOAD = _____

2. DEMAND LOAD = _____

3. WIRE SIZE = _____