SECTION
3.3

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3.3 Electrical Systems

3.3.1 Introduction

NOTE:
Chapter 2 contains additional information pertaining to flood damaged electrical systems.

A building's electrical system can be divided into three components:

1. Power-Handling Equipment
2. Control and Utilization Equipment
3. Wiring

Power-handling Equipment generally consists of bare, weatherproof, or pre-assembled cables, direct-buried or raceway-installed underground cables, transformers, switchboards, meters, distribution panels, large switches, and circuit breakers.

NOTE:
This chapter applies to new and substantially improved structures that must be built in compliance with the minimum requirements of the NFIP. Many of the structures that were built prior to the adoption of floodplain management regulations by communities have building utilities systems that are not resistant to flood damages. For additional information on how to protect building utility systems in these structures, see Chapter 4 on Existing Buildings.

Control and Utilization Equipment generally consists of the various lighting components in a building, and the motors, controls, and wiring devices (i.e., receptacles, switches, dimmers, etc.) used to activate and control such components.

Wiring generally consists of all types of conductors and raceways that are used to provide the interior and exterior electrical wiring needs of a building. An interior wiring system is typically comprised of exposed insulated cables, insulated cables in open raceways, insulated conductors in closed raceways, and combined conductor and enclosure.

Figures 3.3.1A and *3.3.1B* show the typical components of commercial and residential electrical systems. They differ in the size of the service provided as well as the voltage. For commercial buildings, additional components are required to properly regulate the service.

This chapter discusses how to protect electrical systems and components from flood damage under the National Flood Insurance Program (NFIP). Inundation of electrical equipment in a building creates the danger of short circuits, electrical shock, damage of electric components and appliances, injury, fire or even death. In coastal areas, salt water can also cause corrosion that can severely damage electrical components.

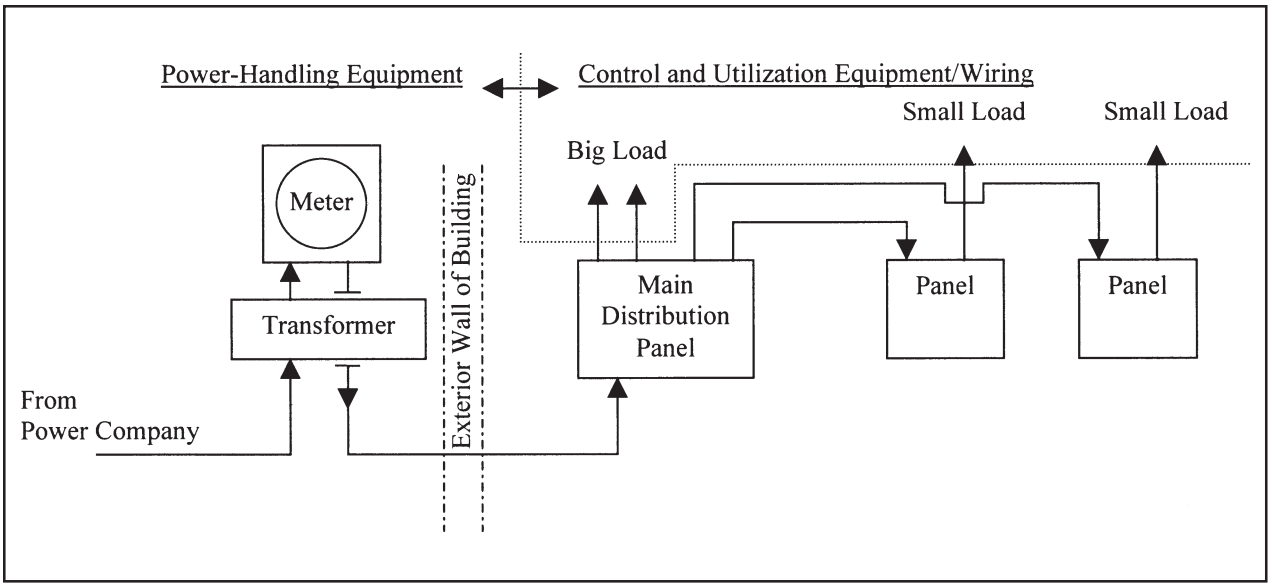


Figure 3.3.1A: Typical electrical system configuration in a commercial application

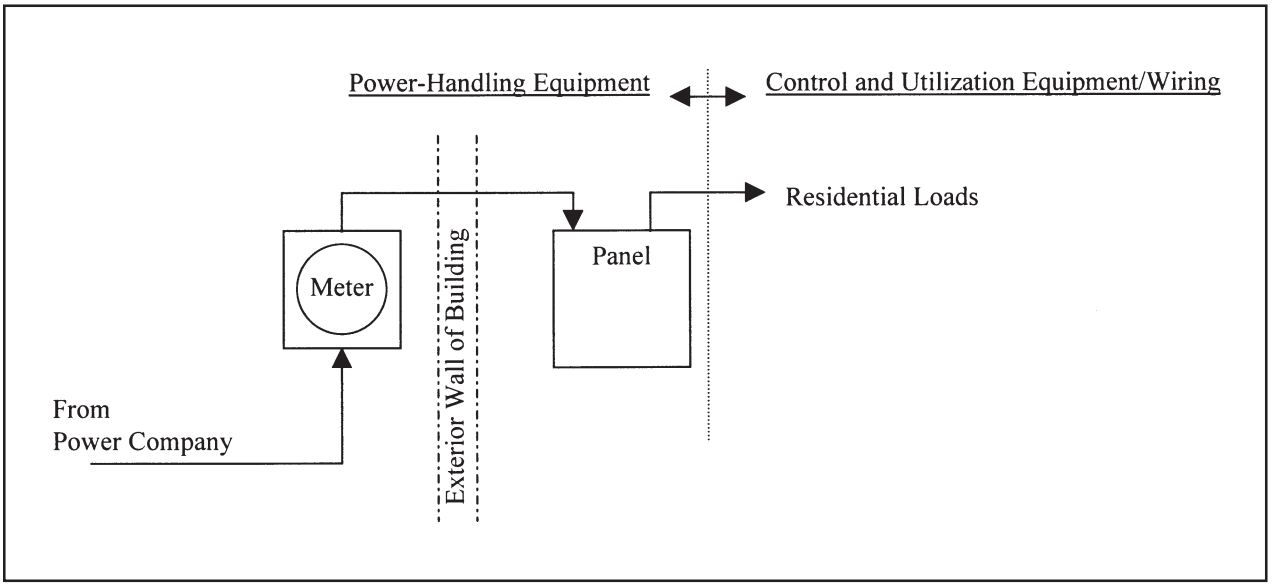


Figure 3.3.1B: Typical electrical system configuration in a residential application

Since contact of live electrical components with water can result in injury or extreme damage, it is best to keep floodwaters from reaching any electrical component.

In general, the figures in this chapter attempt to illustrate some general practices that meet the requirements of the NFIP. Local codes permit many variations that also meet NFIP regulations. Please refer to your local code officials for specific practices that may meet both NFIP regulations and local code.

3.3.2 NFIP Requirements

The NFIP requires that the electrical system in a new or substantially improved structure located in a Special Flood Hazard Area (SFHA) be designed so that floodwaters cannot infiltrate or accumulate within any component of the system. See *Table 3.3.2* for a summary of compliant mitigation methods.

Methods of Mitigation	A Zones	V Zones
1. Elevation	Highly Recommended	Minimum Requirement
2. Component Protection	Minimum Requirement	Not Allowed*

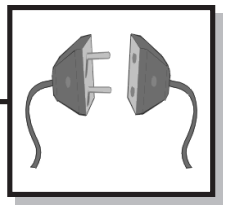
Table 3.3.2: Summary of NFIP regulations
***Allowed only for those items required to descend below the DFE for service connections.**

NOTE:
The Design Flood Elevation (DFE) is a regulatory flood elevation adopted by a community that is the BFE, at a minimum, and may include freeboard, as adopted by the community.

1. **Elevation** refers to the location of a component above the Design Flood Elevation (DFE).
2. **Component Protection** refers to the implementation of design techniques that protect a component or group of components located below the DFE from flood damage by preventing floodwater from entering or accumulating within the system components.

3.3.3 Power-Handling Equipment

Power handling equipment in residential applications typically consists of meters, distribution panels, large switches and circuit breakers. These items are the largest components of the electrical system and are typically the most



expensive to replace. In addition, these components typically provide the link between the electric service provider and the building. Therefore, the protection of these components is particularly important. Power handling equipment in commercial applications typically consists of the same components that are used in residential applications, but additional switches, distribution panels, and even transformers may be added to regulate the larger demand.

Elevation

The most effective flood-resistant design of electrical systems in new and substantially improved buildings in flood-prone areas is elevation of all electrical components to levels at or above the DFE. Elevation gives the most assurance possible that, during a flood, the electrical system components would not be inundated by floodwaters**.** *Figure 3.3.3* shows a residential structure with electrical components located above the DFE.

CAUTION:

The National Electric Code (NEC) specifies a maximum elevation of electric components of 6½ feet above the floor. Refer to your local code officials for similar elevation restrictions.

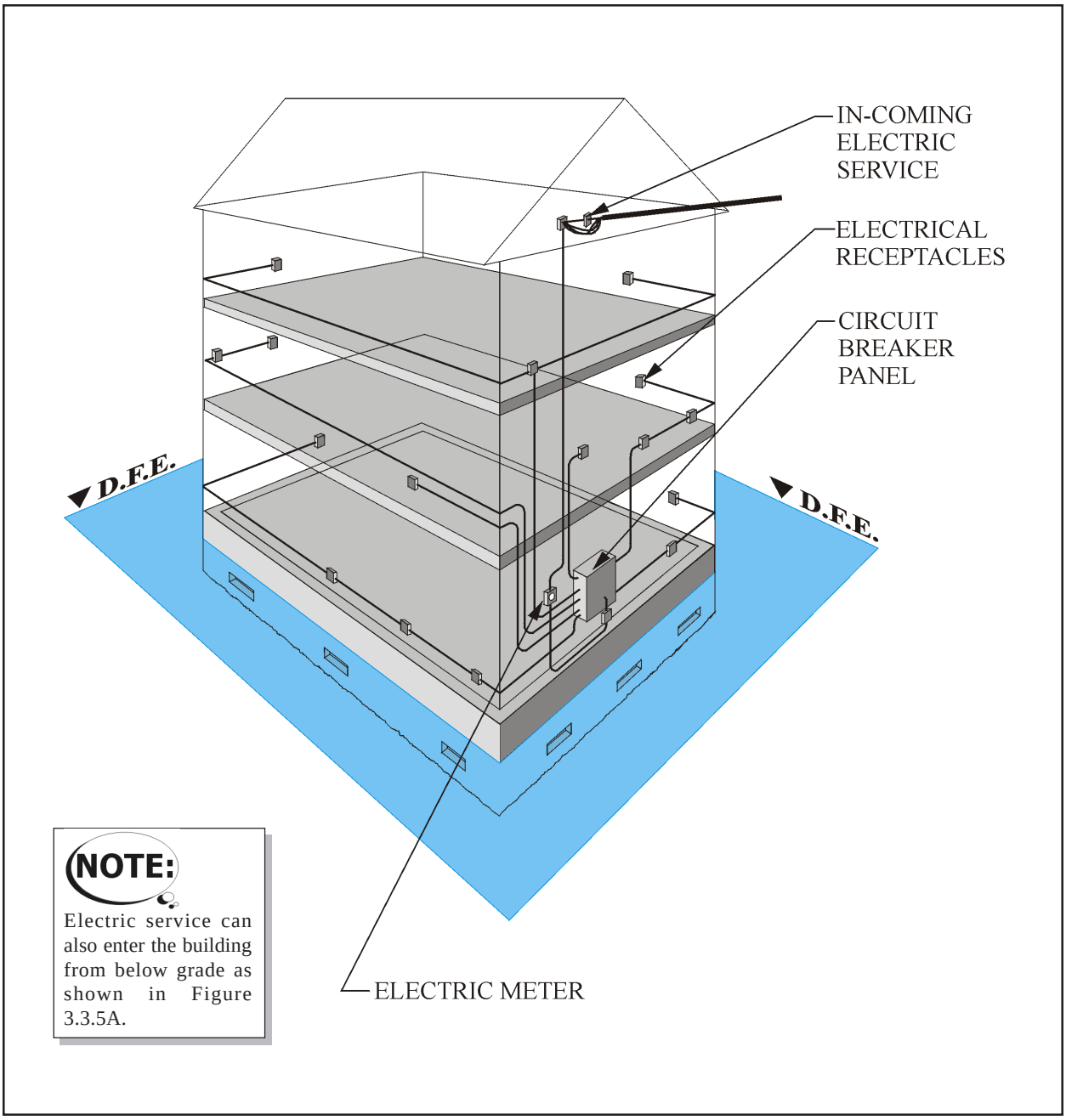
In some situations, the maximum elevation of a component, relative to the floor, is specified. If a component cannot be located above the DFE without exceeding the maximum elevation stipulated by code, it must be relocated to a higher floor within the structure. Or, as an alternative, installation of a platform with stairs to provide access to the elevated electrical components may also meet local code requirements.

Relocation

If raising the equipment above the DFE is not practical, the power handling equipment can be moved to a utility shed that is above the DFE. Relocation of the equipment is an expensive option, but it can be effective in providing elevation of all the equipment. It is used in substantially damaged/improved structures where there is no room to relocate all the electrical equipment and appliances into the main structure above the DFE. In order to elevate the equipment above the DFE a separate structure is built just for housing the electrical equipment. From the separate structure a line is run into a breaker box located in the main structure. The connecting cable between the substructure and the main structure must be above the DFE.

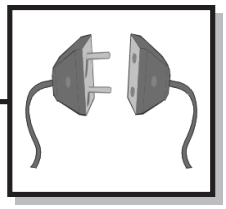
Component Protection

If it is not possible or practical to raise power-handling equipment above the DFE, measures can be taken to protect the equipment at elevations below



NOTE:
Electric service can also enter the building from below grade as shown in Figure 3.3.5A.

Figure 3.3.3: Structure with electrical components located above the DFE



the DFE. For example, a watertight enclosed wall can be built around the electrical equipment that is located below the DFE. The top of the enclosure must be at or above the DFE and there must be a watertight access to the equipment for maintenance.

If electrical components that are supplied power by the distribution panel must remain below the DFE, they can be isolated using the distribution panel. The only electrical components that are permitted below the DFE are the minimum necessary for life/safety. Examples include smoke detectors, simple light fixtures, and switches and receptacles required for areas used for building access, parking, or storage. This design approach groups all of the components that lie beneath the DFE together on Ground Fault Interrupting Circuit (GFIC) breakers. These breakers should be clearly marked so that they can be disconnected in the event of rising floodwaters. This approach leaves other portions of the electrical system to function normally.

NOTE:

All electrical equipment located below the DFE should be on separate Ground Fault Interrupting Circuits clearly marked on the breaker box. This makes it easy to shut off power to all the equipment below the DFE in case of a flood.

The major component that a building owner may not be able to properly locate above the DFE is the meter. Often utility companies want the meter located close to the ground so it is readily accessible for their inspection. Consult the local electrical utility company. Determine if the local electrical utility will permit the meter to be elevated above the DFE with access provided by a stairway and platform. If the company does not permit this, the meter can be located below the DFE, but must be elevated as high as the company permits.

3.3.4 Control and Utilization Equipment

Control and utilization equipment in residential applications generally consists of receptacles, switches, and lighting components. In typical applications, control and utilization equipment will not come in contact with floodwaters because the NFIP requires that the lowest floor elevation be above the DFE. However, exceptions arise in situations where access to an elevated structure requires lighting fixtures/switches below the DFE. The utmost care must be taken to protect life and property in situations where equipment is located below the DFE. This section discusses some basic concepts related to control and utilization equipment as well as guidelines regarding floodproofing of the equipment.

Standard duplex receptacles consist of two sockets, each accommodating a standard plug. In new installations, the three-slot grounded versions of these receptacles are required. Larger appliances sometimes require receptacles rated for additional voltage and amperes. The needs of the equipment that are to be powered dictate the type of plug that is used. If equipment must be located below the DFE, equipment of the lower voltage and amperage types should be used.

Standard wall switches typically control lower voltage applications and could therefore be used below the DFE to control code-required lighting fixtures. Devices that require larger voltages are typically wired directly to the distribution panel and controlled by the associated circuit breaker and need to be located above the DFE.

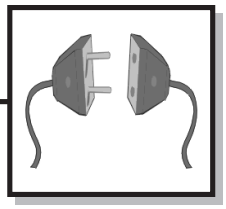
Residential lighting applications typically use standard voltage. Some commercial lighting applications, particularly flourescents, use higher voltages. If codes specify that lighting must be provided in areas that are below the DFE, care should be taken to ensure that only low voltage (120V or less)/ low amperage fixtures be used. They should be regulated by a GFIC breaker that can be used to isolate the circuit in the event of flood conditions.

Wall switches, receptacles, and lighting components are typically interconnected using electric junction boxes and pressure connections. In flood-prone areas, these boxes should be constructed of non-corrosive materials and located above the DFE.

Some equipment is commercially available for marine applications. Depending on the design of the particular unit, it may not be designed to allow proper drainage and drying. If receptacles or light switches must be located below the DFE, they should be of the standard type and, as mentioned elsewhere in this section, will need to be replaced after inundation by floodwaters. This equipment is permitted below the DFE only to the extent required by code for life/safety.

Elevation

As with all electrical components, the optimal approach when designing an electrical system is to locate all components above the DFE. All attempts



should be made to raise control and utilization equipment above the DFE. However, if this is not possible due to local code requirements, then the minimum necessary receptacles, switches, lights, and other components are permitted to be located below the DFE. The distribution panel shall be located above the DFE unless protected from floodwaters entering or accumulating within the panel box.

Component Protection/Isolation

If control and utilization equipment must remain below the DFE, it should be isolated using the distribution panel. The components that lie beneath the DFE should be grouped together on GFIC breakers. In addition, these breakers should be clearly marked so that they can be disconnected in the event of rising floodwaters. This approach leaves other portions of the electrical system to function normally after the portions of the electrical system below the DFE have been disconnected for post-flooding examination and replacement of inundated components.

CAUTION:

Residents should never remain in a structure that has been encircled by floodwaters. The power should be turned off for the whole structure.

3.3.5 Wiring

Wiring are the conveyance lines between the source of energy supply and the equipment that needs the electric energy supply. Most private residential wiring is of type TW Thermoplastic insulated weather resistant or type THW that is both heat and weather resistant. *Table 3.3.5* shows the characteristics of insulated wires (conductors). Any of the wires rated for wet locations are permitted for installation below the DFE.

Individual circuit wire may run through metal or plastic pipes called conduits. More often, circuit wires are combined into cables. Such cables can be either non-metallic sheathed cable (Type NM) or steel armored cable (Type AC). The steel armored cable is usable only in dry indoor locations and is not permitted for installation below the DFE.

Wire connections are typically made with twist-on insulated connectors frequently called wire nuts. The general term for pressure-type connectors, such as wire nuts, is solderless connectors. Pressure connections are adequate for most applications.

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions
Moisture and heat-resistant rubber	RHW*	75C 167F	Dry and wet locations
Thermoplastic	T	60C 140F	Dry locations
Moisture-resistant thermoplastic	TW*	60C 140F	Dry and wet locations
Heat-resistant thermoplastic	THHN	90C 194F	Dry locations
Moisture and heat-resistant thermoplastic	THW*	75C 167F	Dry and wet locations
Moisture and heat-resistant thermoplastic	THWN	75C 167F	Dry and wet locations
Moisture and heat-resistant cross-linked thermosetting polyethylene	XHWN*	90C 194F 75C 167F	Dry locations Wet locations
Silicone-asbestos	SA	90C 194F	Dry locations
Asbestos and varnished cambric	AVA	110C 230F	Dry locations only

Table 3.3.5: Characteristics of insulated wires (conductors)
Source: Extracted from the National Electrical Code
*Suitable for Flood Zones

Elevation and Component Protection

As with power handling equipment, the optimum choice when designing a wiring scenario for a building is to locate all wiring above the DFE, as was shown in Figure 3.3.3. However, in some developments, the wiring that services the buildings is routed underground. In this case, keeping the wiring above the DFE is not possible. The conduit should be of a watertight type and extend above the DFE before the wiring is released from the conduit. *Figure 3.3.5A* shows a residential structure with an underground electrical feed wire. Notice that the underground feed extends vertically above the DFE before the watertight conduit is breached. In addition, the top of the conduit is protected to prevent the infiltration of rain.

In some circumstances the wiring enters the house above the DFE but distribution wiring must extend below the DFE. *Figure 3.3.5B* shows an example

where distribution wiring may be required to extend below the DFE. In situations where wiring must be extended below the DFE, the wiring should be encased in non-corrosive conduit. The conduits should be installed vertically to promote thorough drainage when the floodwaters recede. Wiring should be installed in conduits in these applications because it is easier to replace wiring that is damaged by floodwaters if it is installed in conduit.

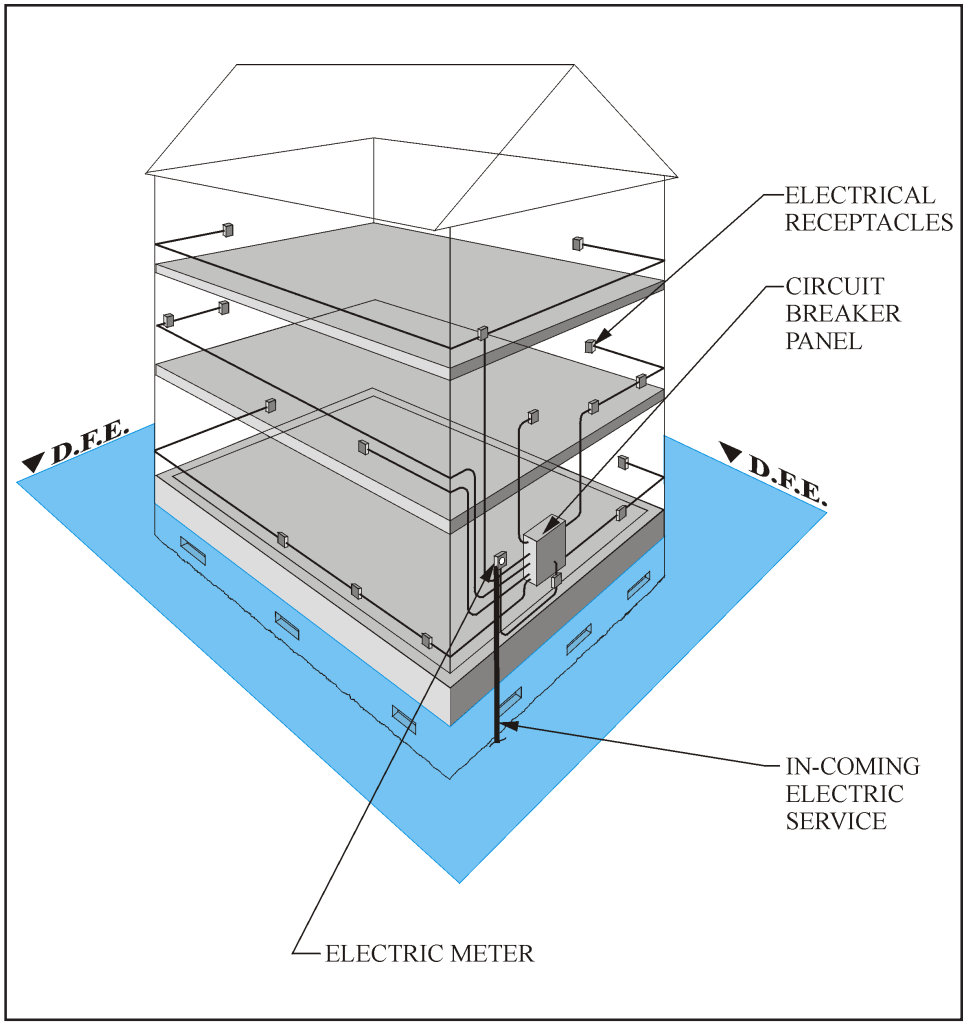


Figure 3.3.5A: Structure with underground electrical feed wire

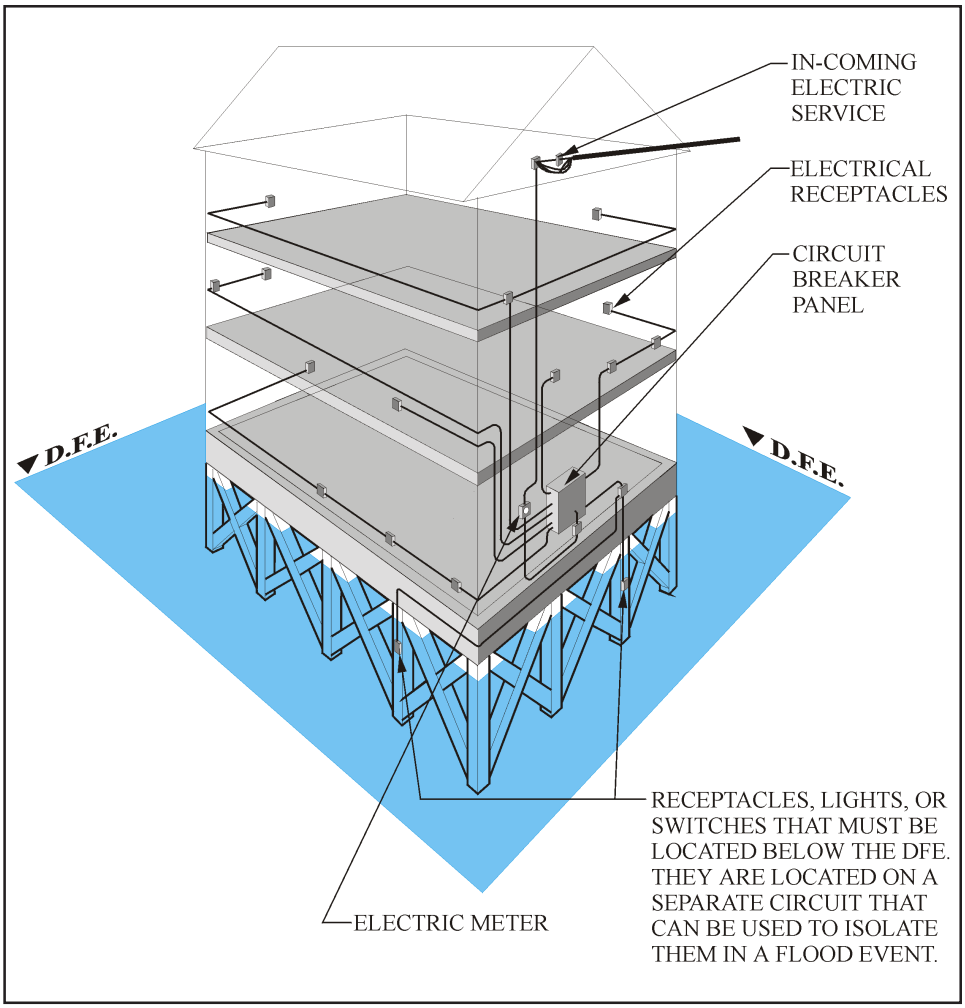


Figure 3.3.5B: Structure with electrical components located below the DFE

3.3.6 Conclusion

Generally speaking, the best approach to minimizing the flood damage to the electrical system of a building is to raise all of the electrical components above the DFE. If the larger components of the structure cannot be relocated to higher elevations, measures can be taken to protect them in place. As a last resort, if some of the smaller components of the system cannot be ele-

vated above the DFE due to local code requirements, design methods can be utilized to minimize the flood damage to the electrical systems of the building so that it can be reoccupied as quickly as possible.

When the electrical system of a building is properly protected from flood damage, the structure can be brought back into operating order more quickly. *Figure 3.3.6* is a flow chart designed to assist you with the design of flood-resistant electrical systems in new and substantially improved buildings. *Table 3.3.6* is a checklist to aid in the review of proposed designs or existing systems for compliance with Federal, State, and local regulations. In addition, a sketch sheet is included that can be used to make additional notes about the system. With a proper assessment of a building and some careful planning before a flooding event occurs, the damage to the building's electrical system can be minimized or eliminated.

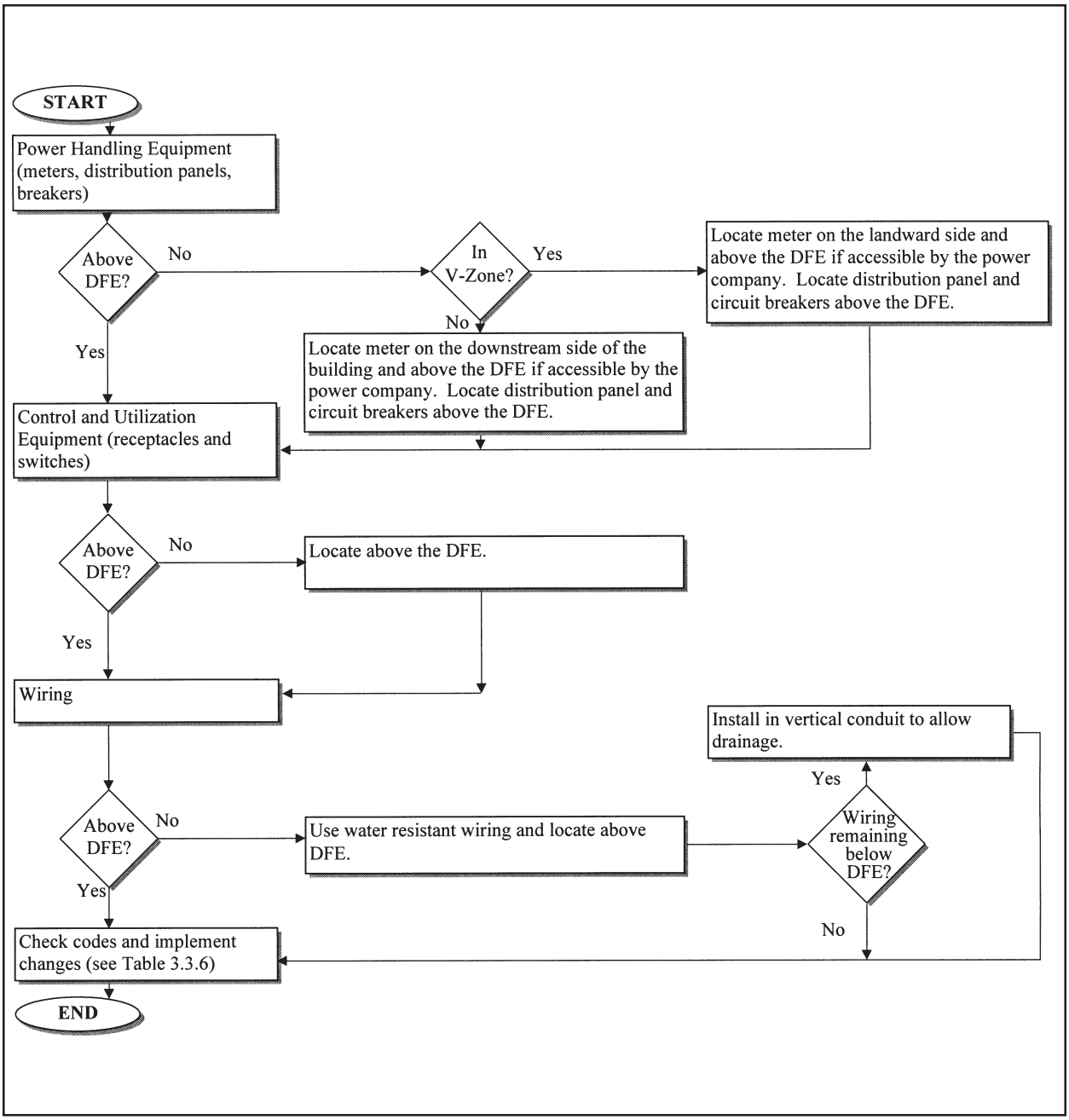
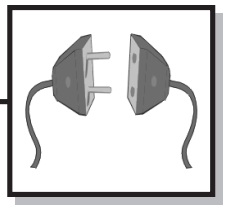


Figure 3.3.6: Flow chart of flood resistant electrical system design



FLOOD RESISTANT ELECTRICAL SYSTEM CHECKLIST

Property ID:	Property Contact:
Property Name:	Interviewed:
Property Address:	Phone:
Surveyed By:	Date Surveyed:

BFE:	

- How Does the Electric service approach the building?

☐ Underground	☐ Pole Mounted

Description:

- Where is the Electric Meter Located? Elevation:

☐ North Side	☐ South Side	☐ East Side	☐ West Side

Description:

- How does the electric service enter the building? Elevation:

Description:

- Where is the distribution panel? Elevation:

Description:

Are the breakers serving circuits below the DFE Ground Fault Interrupting Circuits? ☐ Yes ☐ No

- What equipment is located beneath the DFE?

☐ Meter	☐ Distribution Panel	☐ Lighting	☐ Receptacles	☐ Wiring	☐ Service Entrance
☐ Other:		☐ Other:		☐ Other:	

- What type of internal wiring was observed?

☐ RHW	☐ T	☐ TW	☐ THHN	
☐ THW	☐ THWN	☐ XHWN	☐ SA	☐ AVA

Table 3.3.6: Checklist for flood resistant electrical system design

Sketch sheet
(for details, notes, or data regarding system installations)