

## CHAPTER

## 1

# INTRODUCTION

The purpose of this *Guide* is to present the broad range of knowledge related to the safe installation of electrical wiring and equipment in which an individual must demonstrate proficiency to become qualified as a Master Electrician. The *Guide*, therefore, also serves as a guide to the *National Electrical Code*,<sup>1</sup> hereafter also referred to as the Code, for anyone interested in the design and installation of electrical wiring systems.

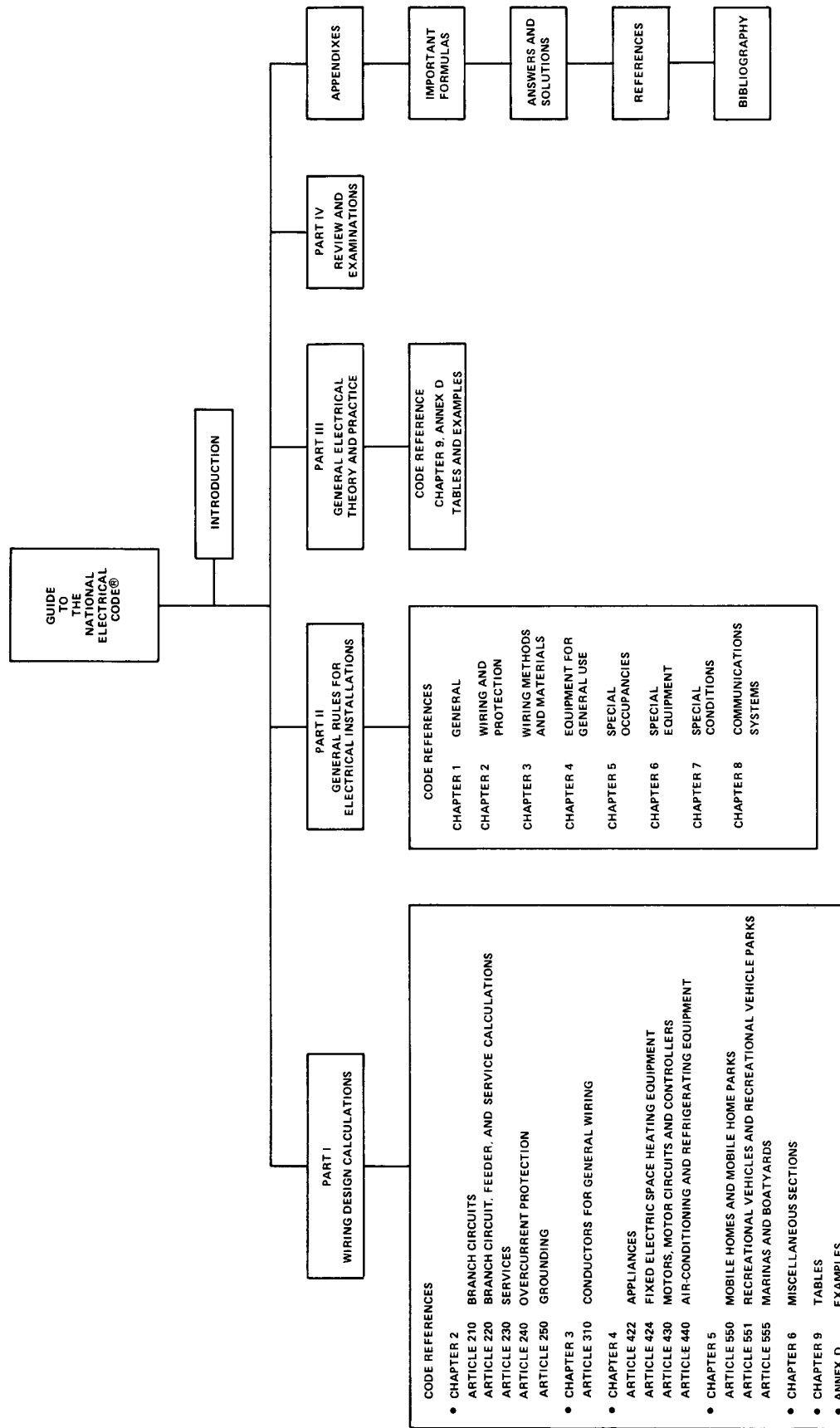
To simplify and organize the material presented, the *Guide* has been divided into four separate and independent parts, as shown in Figure 1–1. Part I of the *Guide* presents discussions, sample calculations, and illustrations that will aid the reader to understand and become proficient in the application of the Code rules for electrical wiring design. Part II of the *Guide* summarizes Code rules covering the installation of electrical wiring and equipment. Part III presents study material covering electrical theory and practice consistent with the level reflected by the questions typically included in Master Electrician's examinations. Part IV contains tests and examinations that are representative of typical Master Electrician's examinations given by city and state licensing agencies.

## 1–1 THE MASTER ELECTRICIAN AND THE MASTER ELECTRICIAN'S EXAMINATION

Although the responsibilities of a Master Electrician vary somewhat from city to city or from state to state, the Master Electrician or his designated representative is normally the only person who may apply to the City Building Office or similar municipal regulatory or

<sup>1</sup>Quincy, Mass.: National Fire Protection Association.

Figure 1-1. Organization of the Guide



inspection agency for a permit to perform electrical contracting work. The Master Electrician is responsible for the supervision and control of the work for which the permit was obtained. The Master Electrician may own his or her own electrical contracting company, hiring other electricians to work for him or her, or the Master Electrician may be employed by an electrical contracting company and act as its representative. In many localities the Master Electrician is required to show not only technical competence but also financial responsibility, usually in the form of workmen's compensation insurance and a bond covering some percentage in dollars of the work to be performed.

The Electrical Board establishes requirements of eligibility of applicants for the Master Electrician's examination. The electrician is usually required to serve a certain number of years as a journeyman electrician. Eligible applicants are administered a test to determine their qualifications to design and safely install electrical wiring and equipment. Applicants who pass the examination and satisfy all requirements established by the Electrical Board are granted a Master Electrician's license.

### 1-1.1 The Examination

The Master Electrician's examination consists of questions and problems that the local examining agency prepares and administers. Most local examinations are given periodically at a time and place specified by the examining board. A usual passing grade is 70% correct for the total examination, although some local agencies administer the test in parts which are graded separately. The form of the examination should be discussed with the examining agency before the test is taken since it varies greatly from locality to locality.

Each local examining agency selects questions that it feels best represent the qualifications required of a Master Electrician in that area; therefore, it is not possible to define a "standard" examination and prepare for it. The topics to be covered on the Master Electrician's examination, however, can be divided into several broad areas from which questions appear on every examination regardless of the locality in which the test is given.

The areas of examination are illustrated in Figure 1-2. These areas include examination questions covering (a) the *National Electrical Code*, (b) general knowledge of electrical practice, (c) supporting theoretical knowledge, and (d) local ordinance rules. In the authors' experience, questions about the Code, including rules and design calculations, usually comprise from 70% to 80% of the examination. Some examining agencies include test questions on local ordinances and installation rules in a separate examination. By comparing Figure 1-2 with Figure 1-1, it is evident that this *Guide* covers all examination areas with the exception of local ordinances and rules. Information on the local material may be obtained from the proper local agency.

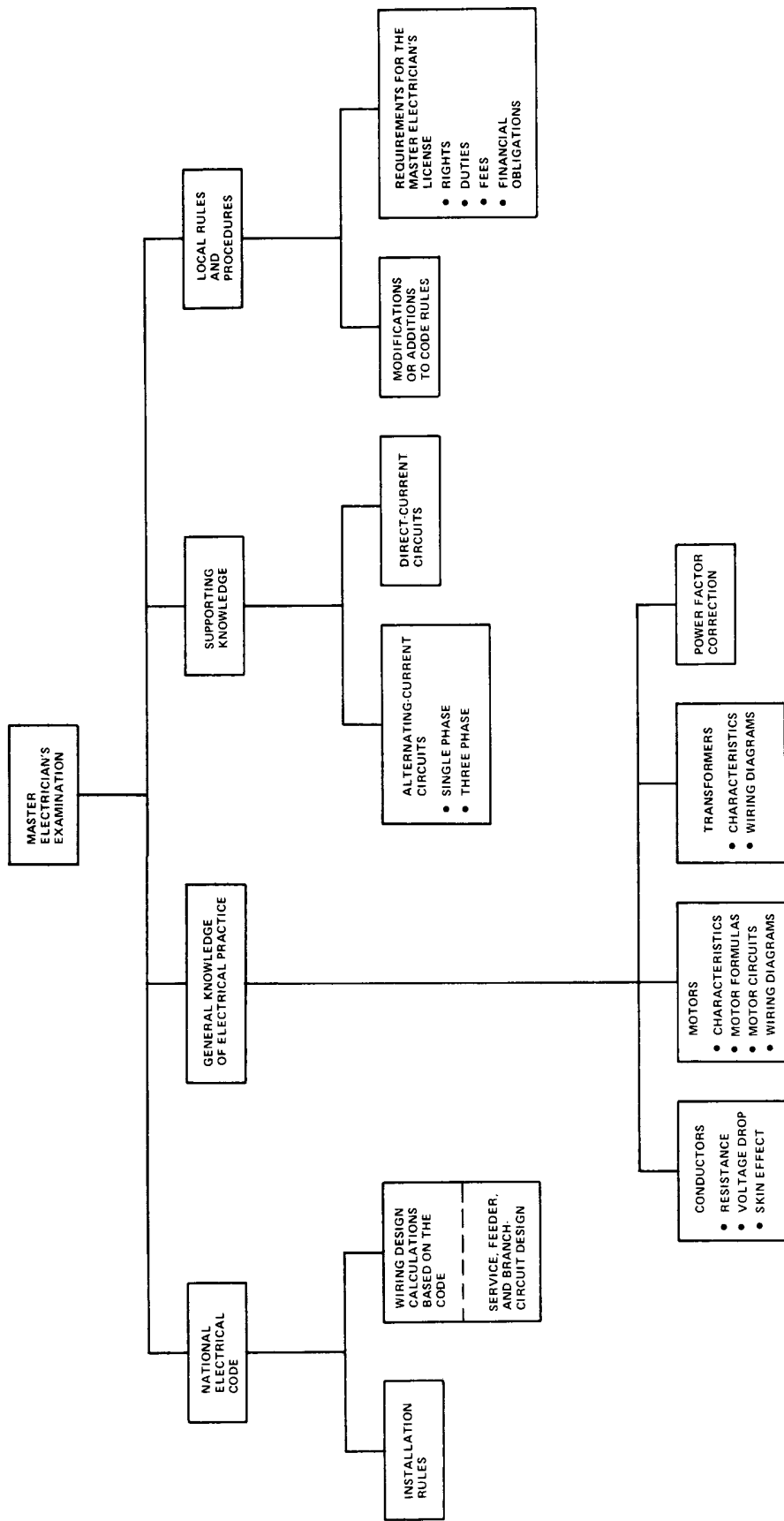
### 1-1.2 The Mechanics of Test Taking

The form of the Master Electrician's examination, the time allowed, and the reference material which the applicant may be allowed to take into the examination room vary with each locality. Typically, an applicant may be allowed from 6 to 8 hours to complete the examination. Most examinations include a closed-book portion for which no reference material, including the Code book itself, may be used. Another portion of the examination is usually open-book with the Code book serving as the primary reference. In some cases, textbooks, notes, and other aids are also allowed as reference material.

The materials an applicant should bring to an examination include:

- a. The approved application form
- b. A working hand-held calculator

Figure 1-2. Major Examination Areas



- c. A large tablet of paper
- d. The latest edition of the *National Electrical Code*
- e. Notes and other reference material (when permitted)

A well-prepared applicant should not have a great deal of difficulty passing the examination if the applicant *reads the questions carefully*, works in an efficient manner, and *checks all answers*.

### 1-1.3 Differences in Grading

Each member of the examining board prepares a certain number of questions on the examination and grades them. If there is any doubt about the meaning of a specific question, the applicant should ask for clarification from members of the board who are present during the examination. They are usually courteous and helpful in this regard.

The solutions to problems, especially when calculations based on Code rules are involved, may differ slightly according to local application or interpretation. The Code usually specifies a maximum or minimum size or rating of conductors and equipment, such as circuit breakers, to be used in an electrical installation. The specified ratings may not coincide with the standard ratings of equipment available from electrical manufacturers. If the applicant is unsure about the expected result to be given as the answer (calculated value or standard size), the applicant should ask a member of the examining board.

## 1-2 HOW TO USE THIS GUIDE

The first two parts of the *Guide* are designed to be studied in conjunction with the Code book. Each article or section of the Code referenced by the *Guide* should be studied thoroughly since the *Guide* summarizes the intent of the Code and does not usually repeat Code rules verbatim. Any article or section not covered or referenced by the *Guide* should nevertheless be read as part of the general study of the Code. The goal should be to have some knowledge of *every* paragraph in the Code even though certain areas might receive greater emphasis by the *Guide*.

Many provisions of the Code that are applicable to the manufacturing of electrical equipment, for instance, are not as important to the practicing electrician as are the rules which apply to the installation of electrical equipment. The rules that apply to the manufacturing of electrical equipment are not covered by this *Guide* in great detail.

An ample number of quizzes, tests, and final examinations has been provided to help the reader measure his or her progress. The answers and method of solution for each question are contained in Appendix B. All problems in the three parts of the *Guide* should be worked and the results checked carefully. The Code rules tabulated in Part II, General Rules for Installations, must be memorized (there is no other way) by repeated study and test taking. The study course outlined by this *Guide* may be supplemented by reading the publications listed in the Bibliography if further study is necessary.

### 1-2.1 International Units and Terms

Since the *National Electrical Code* is an international standard, the code has adopted the metric units of measurements according to the International System of units (SI units). Many dimensions and distances in the Code are thus given in both inch-pound units commonly used in the United States and also the metric equivalent units. In the SI system, the

basic unit of length is the meter (3.281 feet) and the unit of mass is the kilogram (2.205 pounds). Millimeters (mm) are also used for linear dimensions and there are 1000 mm in a meter (m). Thus, a 1-foot length would become

$$1 \text{ ft} = 1 \text{ meter}/3.281 \text{ feet} = 0.305 \text{ m} = 305 \text{ mm}$$

if a direct conversion were used. Such a conversion is a direct mathematical conversion called a “soft” conversion. In many cases, a so-called “hard” conversion is used between units, which does not necessarily represent a direct conversion. For example, 30 inches is approximately 762 mm by direct conversion. The Code may specify the measurement as 750 mm (30"). This is done to simplify measurements in the metric system and to comply with various international standards. In this *Guide*, we will list the inch-pound value first followed by the metric equivalent given in the Code.

The term *luminaire* is used in the Code to mean a lighting fixture as described in the definitions of Article 100. Generally, the terms *luminaire* and *lighting fixture* are interchangeable.

### 1–2.2 Practical Considerations and Code Design

Many of the calculations based on Code rules used in this *Guide* may result in conductor ampacities or service ratings that do not correspond to standard sizes commonly available for construction. This is primarily due to the fact that the Code often specifies the minimum rating for a particular installation. Thus, a load calculation may result in a 196-ampere value for conductor ampacity and overcurrent protection for a service. In practice, a 200-ampere or 225-ampere service panelboard with the appropriate-sized circuit breaker and conductors would be used. In this *Guide*, the exact calculated values for sizes and ratings of conductors and equipment are given except where noted.

## 1–3 THE NATIONAL ELECTRICAL CODE

According to the interesting and informative booklet, *The National Electrical Code and Free Enterprise*,<sup>2</sup> the first *National Electrical Code* was begun in 1896 and published in 1897. The current sponsor of the Code, the National Fire Protection Association, began preparing the Code in 1911. The Code has been revised every few years since then. Each edition of the Code provides a timetable showing the approximate date for the next edition. A few months before the new Code is published, a preprint of the proposed amendments to the last Code is distributed so that local agencies and other interested parties can participate in the rule making or in preparing for the new release of the Code. The latest edition of the Code applied in the reader's locality should be used to accompany this *Guide*.

### 1–3.1 Purpose, Scope, and Enforcement

The purpose, scope, and enforcement of the Code is described in the introductory Article of the Code. Several very important items are mentioned there that bear on the use and interpretation of the Code.

The Code is written for the purpose of safeguarding persons and property from hazards arising from the use of electricity. As is stated in the Code, the Code is *not* a design

<sup>2</sup>Merwin M. Brandon, *The National Electrical Code and Free Enterprise* (Boston, Mass.: National Fire Protection Association, 1971).

specification and it is not an instruction manual. Provisions for future expansion and special considerations must be provided for in an electrical wiring system by the designer.

The Code provides rules covering most electrical installations but excludes those in automobiles and properties not normally accessible to the general public or where other rules are applicable, such as in aircraft. The exact coverage is clearly specified in the Code. The provisions of the Code are advisory as far as the National Fire Protection Association is concerned but they form the basis of local and state ordinances and statutes regulating electrical installations. The interpretation and administration of the Code provisions are usually handled by the electrical inspection agency of the governmental body having local jurisdiction.

### 1-3.2 Organization

The text of the Code includes an article on Administration and Enforcement (Article 80 in Annex G), the Introduction (Article 90), nine chapters, and the Annexes. The rules governing the design and construction of a specific electrical system may be taken from more than one chapter and, in fact, this is usually the case. To simplify the task of the designer and installer of an electrical system, the chapters of the Code are organized into three major groups.

The first group consists of Chapters 1, 2, 3, 4, and 9. The first four chapters present the rules for the design and installation of electrical wiring systems for most of the situations encountered by the Master Electrician. Chapter 9 contains tables which specify the properties of conductors and rules for the use of conduit to enclose the conductors. The examples of Annex D demonstrate the use of the rules for design given in other chapters of the Code.

The second group consists of Chapters 5, 6, and 7. These chapters are concerned with special occupancies, equipment, and conditions. Rules in these chapters may modify or amend those in the first four chapters.

Chapter 8 is the third group and is independent of the other chapters. This chapter covers communications systems, such as telephone and telegraph systems, as well as radio and television receiving equipment.

### 1-3.3 Classification of Code Rules

The Code rules may be divided into three general categories as follows:

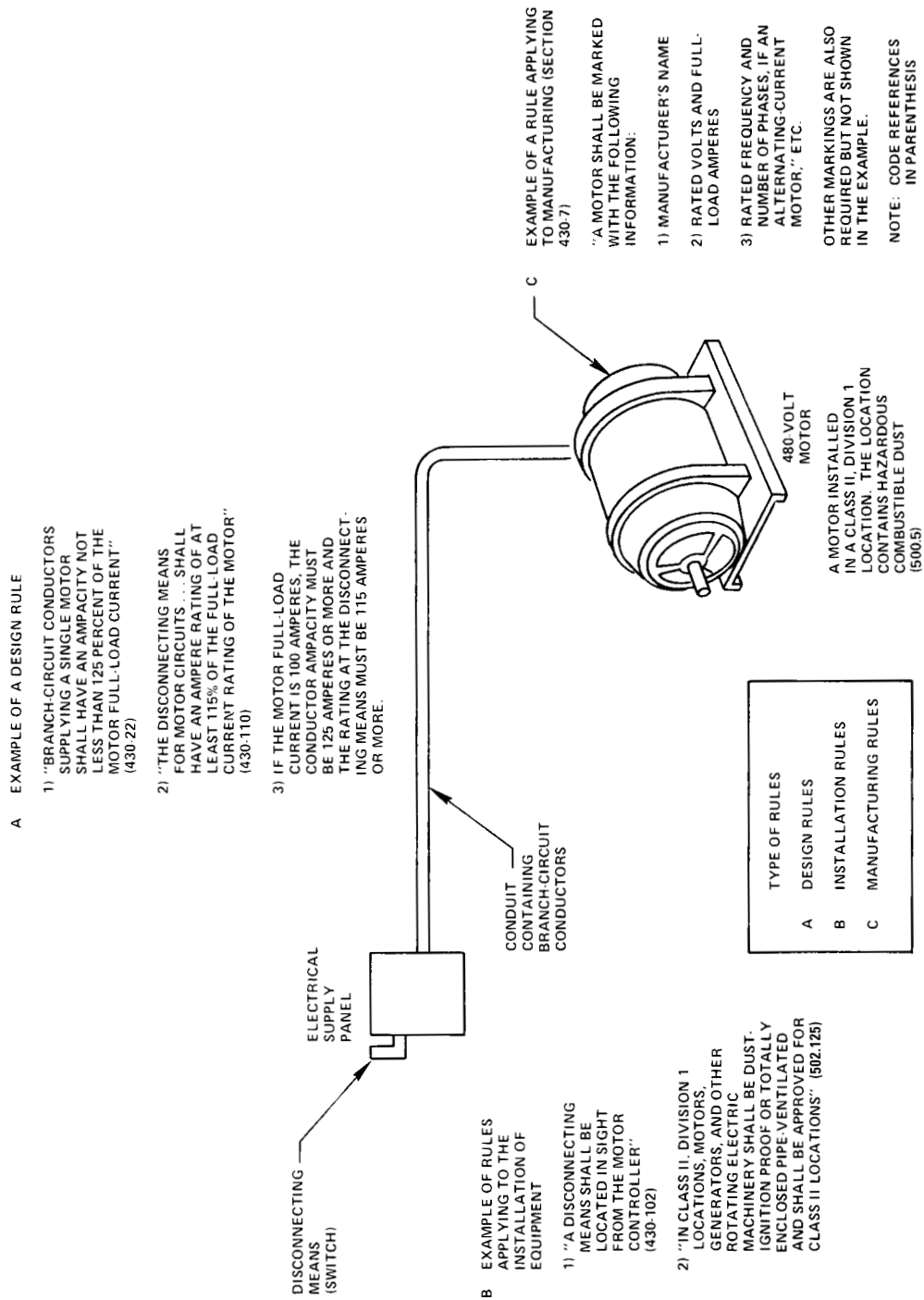
- a. Wiring *design* rules used to determine sizes or rating of circuit conductors and equipment
- b. Rules that specify *installation* requirements for various conditions and occupancies
- c. Rules for *manufacturing* electrical equipment

Figure 1-3 illustrates the application of the three categories of rules. The figure depicts a situation in which a motor is installed in a location in which combustible dust may be present. This type of hazardous location is defined by the Code as a Class II, Division 1 location and certain mandatory provisions are specified for such locations.

One example of a *design* rule in the Code specifies the conductor ampacity<sup>3</sup> (current-carrying capacity of electric conductors expressed in amperes) which must be at least 125% of the full-load current of the motor. The rating of the disconnecting means that disconnects the conductors of a circuit from their source of supply must be at least 115% of the full-load current rating of the motor according to the Code. Thus, if a motor with a full-load current of 100 amperes were used, the conductor ampacity must be at least 125

<sup>3</sup>These terms are defined in Code Article 100.

Figure 1-3. Various Categories of Code Rules Which Apply to a Motor and Its Circuits





amperes. The disconnecting means must have an ampere rating of 115 amperes or more. Other design rules not shown in Figure 1–3 apply to the size or rating of other circuit elements such as the fuses or circuit breaker protecting the circuit.

The rules for *installation* of the motor given in the figure pertain to the location of the disconnecting means within sight of the motor and to the type of motor which may be installed in the Class II, Division 1 location. The rating of the motor (100 amperes) has no effect on these rules for the 480-volt motor used in the example. The design rules and the installation rules, therefore, may be treated separately.

The manufacturer must mark the motor on its nameplate according to the applicable Code rules for the marking of equipment. The information on the nameplate aids both the electrical designer and the installer. The designer specifies the characteristics which the motor must have for a particular installation; the installer must be sure that the correct motor is supplied.

The purpose of separating the rules in this manner is to aid the reader in learning the Code. The design of complete electrical systems must take into account all the rules that apply. The Master Electrician should be thoroughly familiar with the design rules and installation rules presented in the Code. These rules are covered in Parts I and II, respectively, of the *Guide*.

#### 1–4 STATE AND LOCAL CODES AND ORDINANCES

The *National Electrical Code* is not enforced as a nationwide set of rules governing electrical construction practices. Instead, the adoption and enforcement of the Code are under the jurisdiction of local governmental organizations. Many state and local governments adopt the Code and also adopt a supplementary code in the form of state statutes or local ordinances. Article 80 in Annex G of the Code describes an administrative and enforcement structure for a local jurisdiction.

The local ordinances are normally separated into several sections covering legal requirements and technical provisions. The legal section deals with organizational, financial, and other such aspects of electrical construction work. For instance, the responsibilities of the local electrical board would be defined, and the requirements and fees for a Master Electrician's license would be stated. The second portion is of a technical nature and states that the *National Electrical Code* is adopted as the standard code to govern electrical construction. Any local rules that change or supplement the provisions of the *National Electrical Code* would be stated and explained in the technical section.

Local rules should be applied by the Master Electrician whenever they differ from those in the Code. Since the interpretation of the *National Electrical Code* is left to local agencies having jurisdiction, any rule that may be subject to differences in interpretation should be discussed with members of the local electrical board.

**TEST CHAPTER 1**

1. Define a Master Electrician according to the local electrical Code enforced in your area.
2. State the qualifications for a Master Electrician in your area.
3. If you are preparing for a Master Electrician's examination, do the following by contacting the appropriate local agency:
  - (a) Determine the major areas the Master Electrician's examination will cover.
  - (b) Find out the details of the examination and determine the materials an applicant may bring to the examination room.
4. (a) The *National Electrical Code* is not intended as a design specification. True or false?  
 (b) The Code is written to safeguard persons and property from hazards arising from the use of electricity. True or false?
5. What agency enforces the Code in your area?
6. Name the members of the electrical board in your area.
7. Obtain a copy of the local electrical Code ordinance to answer the following questions:
  - (a) State as many differences as you can between the rules of the *National Electrical Code* and the local Code.
  - (b) How may the Master Electrician's license be obtained?
  - (c) How and for what reasons may the Master Electrician's license be revoked?
  - (d) How are local permits for electrical construction obtained?
  - (e) What type of electrical construction work requires a permit?

**COMPREHENSIVE EXAMINATION CHAPTER 1**

Answer the questions before looking up the answers. Then correct your answer if necessary and list the Code reference.  
*Hint: To find the answer to a question, use the extensive Index in the back of the Code.*

1. State exactly the purpose of the *National Electrical Code*.

Answer:

Code Reference: \_\_\_\_\_

2. Name three installations that are not covered by the Code.

Answer:

Code Reference: \_\_\_\_\_

3. Are the Annexes part of the requirements of the Code?

Answer:

Code Reference: \_\_\_\_\_

4. Are Fine Print Notes enforceable requirements of the Code?

Answer:

Code Reference: \_\_\_\_\_

5. Does listed equipment need to be inspected at the time of installation?

Answer:

Code Reference: \_\_\_\_\_

6. Why does the Code limit the number of circuits in a single enclosure?

Answer:

Code Reference: \_\_\_\_\_

7. Suppose the actual size of a product does not correspond to the trade size. Which size is to be used?

Answer:

Code Reference: \_\_\_\_\_

8. It is necessary to be familiar with certain terms defined in the Code to understand the application of the Code. Define the following terms and then check your answers with the definitions in Article 100.

Approved

Authority Having Jurisdiction

Identified (Equipment)

Labeled

Listed

Qualified Person

Special Permission

9. Name at least three considerations to be used when examining equipment.

Answer:

Code Reference: \_\_\_\_\_

10. How shall electrical equipment be installed?

Answer:

Code Reference: \_\_\_\_\_