NUREG/CR-5228
PNL-6653
BHARC-700/88/017
Vol. 2

Techniques for Preparing Flowchart-Format Emergency Operating Procedures

User's Manual (Sections 10.0-17.0)

Manuscript Completed: September 1988
Date Published: January 1989

Prepared by
V.E. Barnes, C.J. Moore, D.R. Wieringa,
C.S. Isakson, B.K. Kono, Battelle Human Affairs Research Centers
R.L. Gruel, Pacific Northwest Laboratory

Battelle Human Affairs Research Centers
Seattle, WA 98105

Pacific Northwest Laboratory
Richland, WA 99352

Prepared for
Division of Licensee Performance and Quality Evaluation
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN I2006

ABSTRACT

This two-volume report describes the activities, findings, and recommendations of a project entitled "Techniques for Presenting Flowchart-Format Emergency Operating Procedures." The project team surveyed the literature pertaining to flowcharts, reviewed existing flowchart emergency operating procedures (EOPs), interviewed consultants who produced flowcharts, and interviewed reactor operator licensing examiners about the use of flowcharts in nuclear power plants.

Volume 1 of this report discusses the use of flowchart-format EOPs in nuclear power plants and presents issues to be addressed in the design and implementation of flowchart EOPs. Volume 2 presents techniques for preparing flowchart EOPs that were derived from the information discussed in Volume 1 and from NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures (USNRC, 1982).

EXECUTIVE SUMMARY

The two volumes of this report discuss the flowchart-format emergency operating procedures (EOPs) used in nuclear power plants. Volume 1 discusses design principles and implementation issues that should be considered in preparing flowchart EOPs. Volume 2 presents techniques for designing and implementing flowchart EOPs that are derived from the principles discussed in Volume 1.

Emergency operating procedures are "plant procedures that direct operators' actions necessary to mitigate the consequences of transients and accidents that have caused plant parameters to exceed reactor protection system set points or engineered safety feature set points, or other established limits" (USNRC, 1982, p. 3). Historically, EOPs have been presented in text format as a series of steps. Recently, however, many licensees have begun to present their EOPs as flowcharts.

Flowcharts are a means of presenting a procedure by combining text with graphics. This report considers two types of flowcharts: (1) algorithmic flowcharts, which are flowcharts as we usually consider them; and (2) big-picture flowcharts, as they are known in the industry, which are a hybrid of a traditional flowchart and a text procedure. Big-picture flowcharts have evolved in the nuclear power industry in response to the need to present multiple procedures that must be performed concurrently.

Traditional algorithmic flowcharts and three variations on the traditional format are discussed: (1) logic trees, (2) Nassi-Schneiderman flowcharts, and (3) nested boxes. The traditional flowchart uses symbols of various shapes as boxes that enclose small bodies of text. The shape of the symbol indicates the type of text that is enclosed in the box; for example, decision steps are phrased as questions and enclosed in a diamond, and action steps are enclosed in a rectangle. These symbols are connected by lines, called flowlines. Users follow a flowpath through the flowchart and perform steps as they are encountered. Flowpaths divide at decision symbols--typically into two flowpaths, one if the answer is yes, one if the answer is no--but can merge later in the flowpath.

Logic trees are very similar to traditional flowcharts, except that flowpaths do not merge. Thus, a logic tree grows wider from beginning to end, as flowpaths divide at decision symbols and do not merge again. Logic trees are most commonly used for diagnostic procedures, which contain many questions and few action steps. Because their flowpaths do not merge, logic trees for complicated procedures would be large and unwieldy.

Nassi-Schneiderman flowcharts excel at showing the hierarchical relationships that are not evident in traditional flowcharts and logic trees. The most striking feature of the Nassi-Schneiderman flowchart is that it does not contain flowlines; instead it consists of a series of boxes, stacked or set one inside the other. All boxes share a common right border. Boxes that are stacked indicate steps that are performed sequentially. If boxes are nested inside each other, the outermost box is a loop, indicating that the steps in the inner boxes are to be repeated.

Nested-boxes flowcharts are quite similar to Nassi-Schneiderman flowcharts. However, the boxes are nested completely inside each other and do not share a common border.

Although Nassi-Schneiderman and nested-boxes flowcharts show hierarchical relationships well, they do not present referencing and branching information well and can be visually dense and difficult to follow. For these reasons, they are not well-suited for the presentation of EOPs.

Consequently, the algorithmic flowcharts used in the nuclear power industry are either of the traditional or logic tree format. Several studies have indicated that algorithmic flowcharts are an aid to decision-making; reactor operators using algorithmic flowcharts ought to make fewer errors than those using text procedures if the task requires many decisions. However, algorithmic flowcharts have disadvantages when used in the nuclear power industry: (1) algorithmic flowcharts are not the best format for presenting a procedure that contains many actions and few decisions; (2) the situation in a nuclear power plant can be so complicated that it will not lend itself well to a rigid algorithmic analysis; (3) algorithmic flowcharts divide decisions into such simple steps that the relationship between these steps is not evident; and (4) when broken down into true algorithms, flowcharts quickly become cumbersome and difficult to use. Because of these deficiencies, algorithmic flowcharts should only be used in situations where their advantages as decision aids outweigh any drawbacks. Two such situations are diagnostic flowcharts, which would refer operators to text EOPs once the problem was diagnosed, and the Critical Safety Function Status Trees used in Westinghouse plants.

Big-picture flowcharts are used primarily by members of the General Electric (GE) Boiling Water Reactors (BWR) Owners' Group and were developed in response to this owners' group's philosophy of emergency event mitigation, which requires operators to execute several procedures concurrently. Operators using text procedures based on the GE BWR Owners' Group's emergency procedure guidelines encountered severe placekeeping difficulties. Big-picture flowcharts, which present the procedures that are to be executed concurrently side-by-side on a large sheet of paper, are a solution to these placekeeping problems. Big-picture flowcharts are a hybrid of text and flowchart. Because a simple graphic presentation is important in big-picture flowcharts, many of the attributes of algorithmic flowcharts, which simplify decision-making but are graphically complicated, cannot be used in big-picture flowcharts. Thus, big-picture flowcharts are not decision aids. Big-picture flowcharts are easier to use than equivalent text procedures, but are not a complete solution to the difficulties that may arise when operators are required to perform several tasks at once.

Several principles of graphic design are important to the preparation of effective flowcharts. These principles were derived from the literatures on flowchart design, graphic design, cartographic design, and cognitive psychology, and from interviews with flowchart designers. Flowcharts should be designed according to the principles of contrast, unity, proportion, rhythm, simplicity, and consistency. In following these principles, the flowchart designer must effectively manipulate the visual variables of position, implied movement, shape, orientation, size, value, color, and texture. For example, the variation of value--that is, lighter and darker shades--provides the contrast that is essential to pick out an entry point in a cluttered flowchart. The use of the same shape to enclose the same type of information provides the consistency that enables users to always recognize the meaning of that symbol. Effective use of position and implied movement--that is, the placement of symbols and the flowlines that connect them--can make a complicated flowchart much easier to understand.

Flowchart layout is facilitated by using basic flowcharting structures: linear, alternative, repetitive, divergent, case, bypass alternative, decision-follows-the-action, and abnormal-exit. Basic structures are the combinations of flowlines and symbols that make up a flowpath. Using only the basic structures, flowchart designers can create any logical sequence of steps. These structures should be used at several levels; for example, a repetitive structure can become part of a larger alternative structure. If flowchart designers construct flowcharts by nesting the basic structures in this manner, the overall organization of the flowchart will be apparent to the designers and to the users of the flowchart.

Flowchart designers must keep other principles in mind when designing a flowchart. The design of the flowchart must not create any visual illusions, such as figure/ground illusions, in which items in the background appear as items in the foreground. The flowchart should not be so complex that important information is not apparent to users. Type in the flowchart should be readable at the distance from which the flowchart will be read and under the lighting conditions in the control room, including degraded lighting. Decision tables should be used to simplify the logic in big-picture flowcharts. The level of detail in the flowchart, which is often less than in a corresponding text procedure, should not be so low that newly certified operators will not understand the procedure. Operator training programs must specifically address the low level of detail in flowcharts. The problems caused by using large flowcharts in a small control room should be addressed, as should the problems that will be encountered when producing and revising graphically complex flowcharts.

Specific techniques for flowchart designers are presented in Volume 2 and were derived from the design principles and other considerations discussed in Volume 1 of the report. These techniques are intended to assist flowchart designers in integrating and applying the complex considerations that must be addressed to prepare usable flowchart EOPs. However, because so little empirical research has been conducted to assess flowchart-format procedures, the techniques presented in Volume 2 should be viewed as hypotheses that await evaluation through further research and actual use of flowchart-format EOPs.

ACKNOWLEDGMENTS

A number of individuals contributed significantly to the preparation of this report. The authors wish to thank Mr. Jim Bongarra, Dr. Michael Goodman, Dr. Jay Persensky, and Mr. Bill Regan for their guidance and support in conducting this project. Mrs. Charleen Sager, Ms. Anita Freeze, and Ms. Carol Johnson were invaluable members of the project team. In addition, the flowchart designers interviewed for the project were more than kind to give freely of their time and extensive knowledge. All of these individuals have our sincere appreciation.

CONTENTS

CONTENTS (cont'd)

LIST OF FIGURES

LIST OF FIGURES (cont'd)

10.0 INTRODUCTION

The purpose of this volume is to assist flowchart designers in preparing usable flowchart EOPs. The techniques presented here are derived from the basic principles of flowchart design described in Sections 3.0 through 8.0 of Volume 1 of this report, and from the principles of EOP development described in NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures (USNRC, 1982).

Volume 2 is not intended to be a stand-alone document. The preparation of usable flowchart EOPs is a difficult process that requires the flowchart designer to make complex choices among the many, often conflicting, principles of graphic design and procedure presentation. For example, cautions should be placed in the flowpath where they will not be missed, but the flowchart must not be graphically dominated by long cautions. When faced with a long caution, the flowchart designer must balance the principles of information availability, graphic communication, and consistency (i.e., should long cautions be treated differently from short cautions in the flowchart?). Consequently, a thorough understanding of the material presented in Volume 1 will be beneficial when applying the techniques presented in Volume 2.

To assist flowchart designers in making the trade-off decisions that they will confront in developing flowchart-format EOPs, the relevant sections in Volume 1 or in NUREG-0899 that provide the basis for each technique presented in Volume 2 are referenced.[1] In addition, the techniques in this volume have been written to be as specific as possible. Where numerical values for variables such as type size are necessary, those values are provided based upon a set of assumptions that are described in Appendix D. In plants where these assumptions will be violated, flowchart designers will be required to calculate their own values using the methods described in Appendix D.

Without knowing what type of flowchart format has been selected and the purpose that the flowchart is intended to serve at a particular plant, however, it has not been possible to describe all techniques precisely. Thus, some of the recommendations for positioning flowchart items use relative terms (e.g., "close to" and "farther from"). Consequently, individual flowchart designers will be required to draft flowcharts and to conduct usability tests with operators at their plants to ensure that consistent and meaningful visual patterns are created in the flowcharts.

Volume 2 is divided into eight sections. Section 11.0 provides information to assist a licensee in deciding whether or not to present EOPs as flowcharts, and, if so, in which of the two flowchart formats currently used in the nuclear power industry. Section 12.0 presents techniques for laying out flowchart EOPs. Section 13.0 discusses the types of information typically presented in flowchart EOPs, and Section 14.0 provides techniques for presenting text in flowcharts. Emphasis techniques in flowcharts are

---

[1]All references are to Volume 1 of this report unless NUREG-0899 is specifically indicated in the reference.

discussed in Section 15.0, while Section 16.0 presents techniques for the use and maintenance of flowchart EOPs. Section 17.0 discusses deviations from the techniques described in this report.

11.0 THE FLOWCHART ALTERNATIVE AS AN EOP FORMAT

Flowcharts for presenting EOPs can be divided into two groups; flowcharts that are written as algorithmic decision aids (algorithmic flowcharts; see Figure 11.1), and diagrams that use flowcharting techniques to present instructions on how to perform two or more tasks concurrently (big-picture flowcharts; see Figure 11.2). A well-designed algorithmic flowchart will not provide the big picture, and a well-designed big-picture flowchart will not serve as an algorithmic decision aid. Algorithmic flowcharts can be structured to provide some big-picture information to operators, and decision aids can be incorporated into big-picture flowcharts; but the two types of flowcharts are designed around different central purposes and are thus very different. Both types of flowcharts have advantages and disadvantages when compared with text. Thus, when considering the flowchart alternative, licensees must consider their specific procedure needs; and the strengths and weaknesses of text procedures, algorithmic flowchart procedures, and big-picture flowchart procedures.

Text procedures have several advantages over flowcharts. Text procedures can present information through various formatting devices that are not easily incorporated into flowcharts. For example, headings, subheadings, and a hierarchical system of step numbering can be used in text procedures to show how the task to be performed is organized. These devices cannot be used as effectively in flowcharts because they clutter the flowchart page. In addition, text procedures can incorporate detailed information more easily than can flowcharts. Further, text procedures are generally easier to revise and reproduce than are flowcharts.

Flowcharts, however, can convey organizational information more precisely than text procedures. The manner in which symbols are positioned on the page, how operators are directed to move through the flowchart, and the use of various graphic cues can reveal information about the task that would require extensive explanation in a text procedure. Also, a procedure with many internal branches may be easier to use and to understand when formatted as a flowchart: flowlines are easier to follow than "GO TO" statements in text. Certain graphic conventions are especially well suited to presenting some types of steps found in EOPs. For example, in flowcharts a large dark symbol that brackets other symbols is an excellent way of presenting steps of continuous applicability, and an octagon-shaped symbol is a good means of indicating hold points in a procedure.

The principal advantage of algorithmic flowcharts is that they simplify decision making by breaking a complex decision with many antecedents into its component parts, so that operators using them are less likely to commit errors than operators using text procedures. Algorithmic flowcharts have the following disadvantages: (1) algorithmic flowcharts are not the best format for presenting lists of action steps; (2) emergency events in a nuclear power plant can be so complicated that mitigation may not lend itself to a rigid algorithmic analysis; (3) algorithmic flowcharts divide processes into such simple steps that the relationships between these steps are not evident; and (4) when broken down into true algorithms, flowcharts quickly become cumbersome, making it difficult to include adequate detail in the flowcharts.

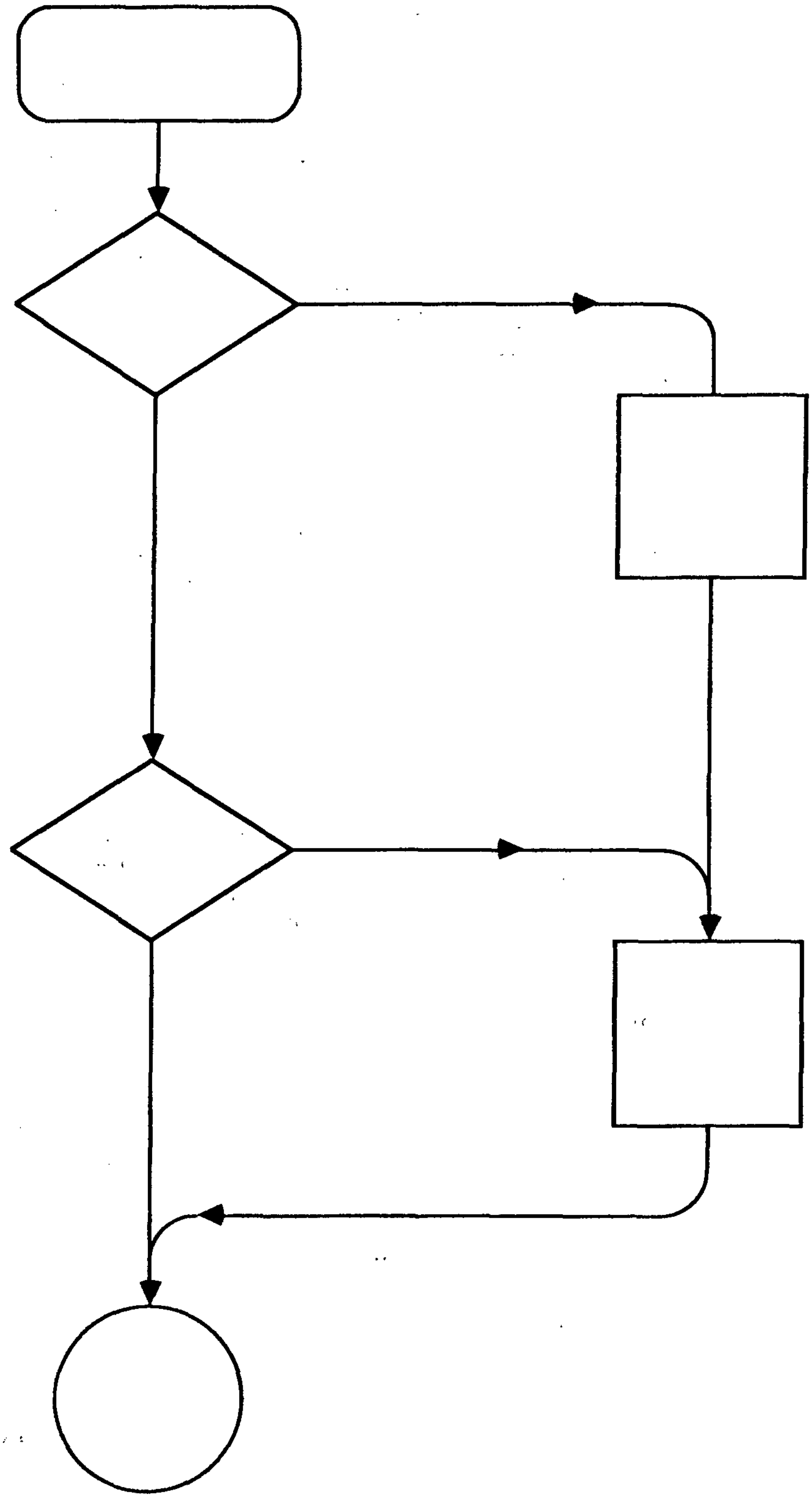


FIGURE 11.1. Algorithmic Flowchart

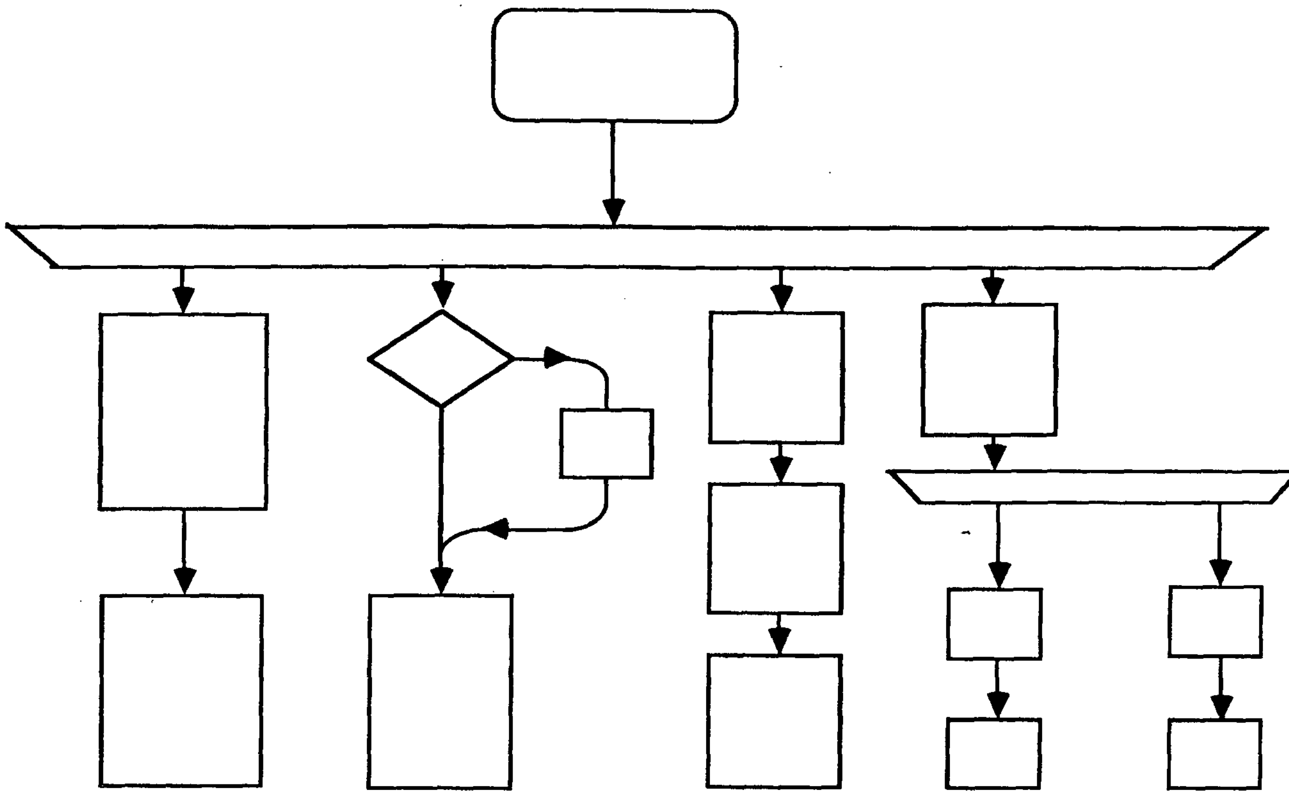


FIGURE 11.2. Big-Picture Flowchart

Algorithmic flowcharts are likely to be more usable than text procedures if the strengths of the algorithmic approach for assisting in decision making can be exploited. However, any procedure preparer who decides to revise an entire set of EOPs to become a series of algorithmic flowcharts will certainly encounter difficulties. The flowcharts may be large, complicated, and difficult to use. However, because algorithmic flowcharts can be so beneficial as decision aids, procedure preparers should consider presenting EOPs that contain many decisions as algorithmic flowcharts. For example, procedures for diagnostic tasks can be effectively presented in an algorithmic flowchart format.

The principal advantage of big-picture flowcharts is that multiple procedures that are performed concurrently can be presented side by side on one sheet of paper. Also, steps of continuous applicability can be presented effectively in big-picture flowcharts. Big-picture flowcharts can incorporate formatting techniques common to text procedures, such as step numbering, to a limited degree. However, big-picture flowcharts have the following two disadvantages: (1) when procedures that are not presented on the same page must be concurrently executed, operators will be required to manipulate several large flowcharts, a process that may be more difficult than manipulating several relatively smaller text procedures; and (2) in order to prevent disruptive page breaks in procedures, it may be necessary to minimize the technical detail provided in the flowchart. In spite of these disadvantages, big-picture flowcharts should be considered when multiple procedures must be executed concurrently and can be presented on one page.

12.0 FLOWCHART LAYOUT

The most important and difficult task facing a flowchart designer is to organize the information contained in an EOP so that it can be presented in the flowchart format. Flowchart layout entails arranging symbols on the flowchart page and using graphic techniques to guide movement through the flowchart so that the image presented is consistent with the technical requirements of the procedure and meets the goals of legibility, meaningfulness, and aesthetics. The use of basic flowchart structures to present units of information within the flowchart, effective construction of flowlines, the use of flowlines and connector symbols to manage referencing and branching in procedures, and the appropriate placement of column and page breaks contribute an optimal flowchart layout. The following sections present techniques for addressing these issues.

12.1 USING BASIC STRUCTURES TO FACILITATE MOVEMENT THROUGH A FLOWCHART

Eight basic structures (i.e., arrangements of flowchart symbols) can be used to convey most of the logical relationships found in EOPs (Section 6.3, p. 6-4). These eight structures, as shown in Figures 12.1 through 12.3, are as follows: (1) linear; (2) alternative; (3) bypass alternative; (4) divergent; (5) repetitive; (6) decision-follows-the-action repetitive; (7) abnormal-exit repetitive; and (8) case. To form flowpaths, each structure can be arranged linearly in a flowchart or can be nested within one or more other structures (Section 6.3.3.1, p. 6-14).

When linking basic structures to form flowpaths, capitalizing upon the left-to-right and top-to-bottom reading patterns of English-speaking people will establish two natural directions of movement in flowcharts. When the top-to-bottom direction is consistently used as the primary direction of movement, and the left-to-right direction is used for the secondary direction of movement, the flowchart tends to naturally assume a degree of order and to fall into columns (Section 5.3.2.1, p. 5-16; Section 6.2, p. 6-2). To clearly convey the organization of the procedure and to guide movement through flowcharts, use the following techniques.

- Use the basic structures as tools in designing the flowchart to assist in organizing information and to help ensure that operators are provided with consistent and meaningful visual presentations of information (Section 6.3, p. 6-4).

- When designing the flowchart layout, do not sacrifice the legibility of the symbols, flowlines, or text, the meaningfulness of the graphic cues used, or the aesthetics of the flowchart to save space on the page (Section 4.0, p. 4-1).

- Separate flowpaths with white space. Ensure that the amount of space between flowpaths is wide enough so that operators can follow paths without incorrectly moving from one path to another. A rule of thumb might be to provide a column of white space that is 1 1/2 - 2 times as wide as the average width of the widest flowpath on the page (Section 4.1, p. 4-1).

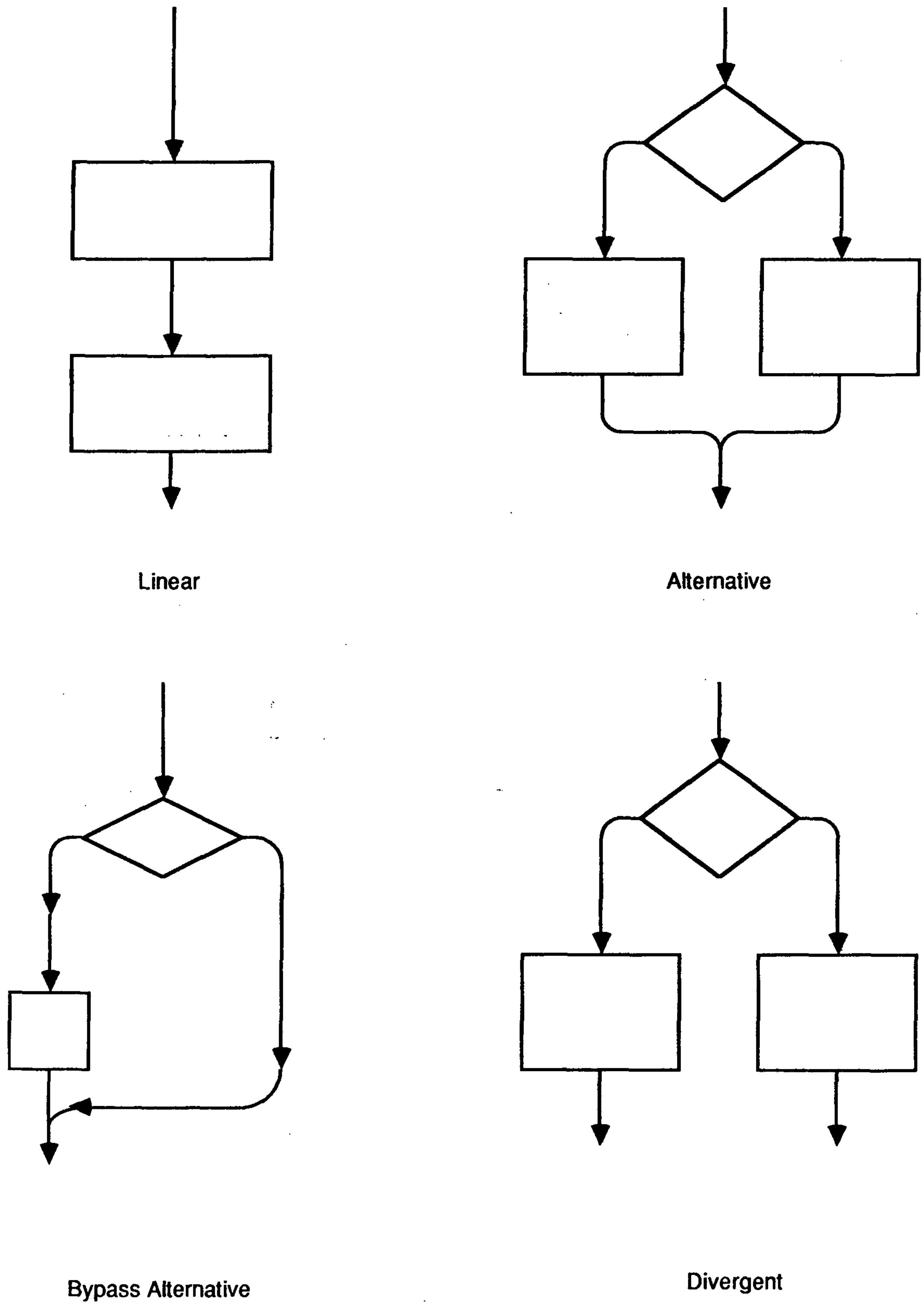
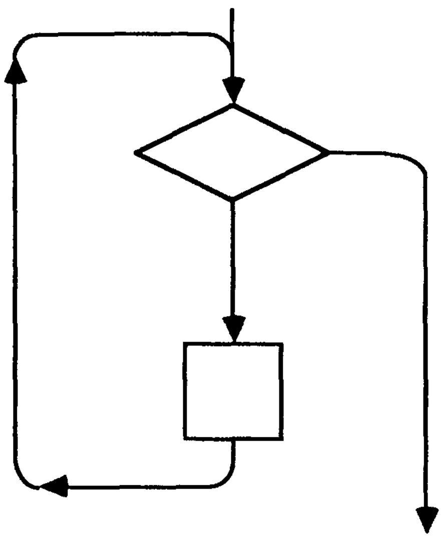
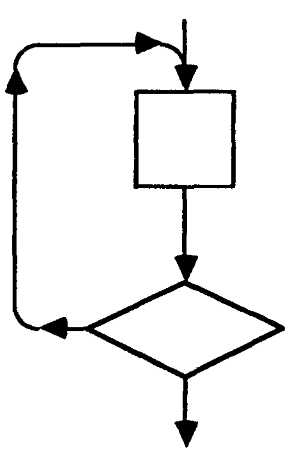


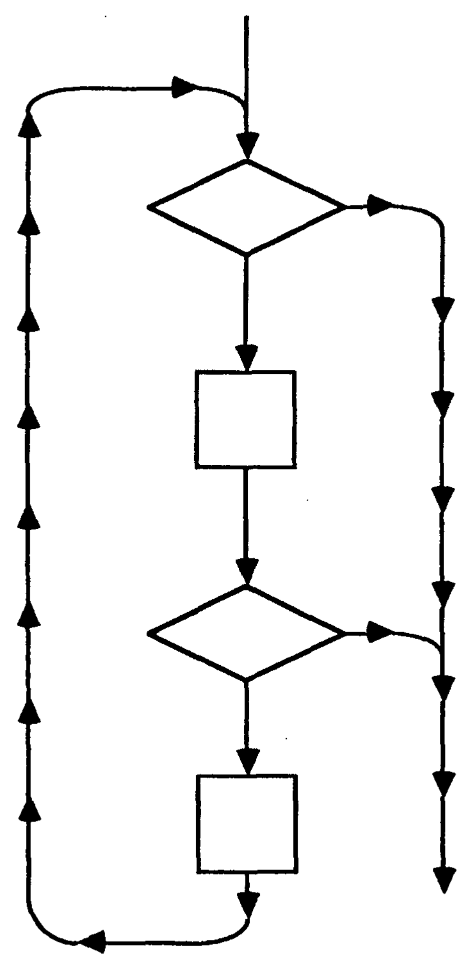
FIGURE 12.1. Four Basic Structures for Flowcharts



Repetitive



Decision-Follows-the-
Action Repetitive



Abnormal-Exit Repetitive

FIGURE 12.2. Three Basic Structures for Flowcharts

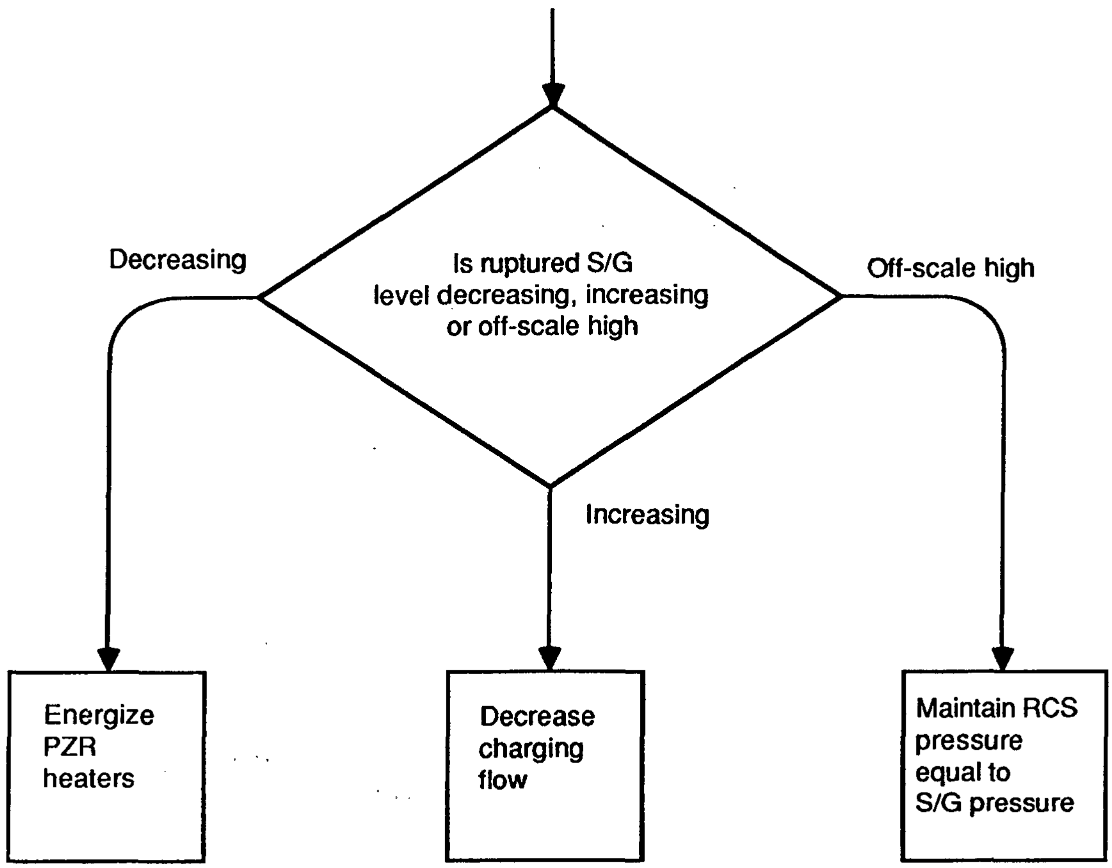


FIGURE 12.3. Case Structure

- Ensure that the primary flow of movement in the flowchart is from top-to-bottom so that the principal action and decision steps in the procedure follow one another straight down a column. When performing a series of steps (actions and decisions), operators should move farther down the page with each step (Section 5.3.2.1, p. 5-16; Section 6.2, p. 6-2).

- In flowpaths that direct movement from top-to-bottom (i.e., vertical flowpaths), ensure that flowlines enter all symbols at the top center of the symbol. If the flow of movement entering a rectangular symbol is from above, then the flowline should exit from the bottom center of the symbol (Section 6.4.6, p. 6-35).

- If a single flowpath must be formatted as several columns on a page, arrange the columns so that operators progress through the columns from left-to-right (Section 6.2, p. 6-2).

- Do not sequence a series of steps connecting two vertical flowpaths so that the sequence must be read from right-to-left. Avoid overall organizations that require this pattern of movement (Section 6.2, p. 6-2). If this pattern cannot be avoided, then structure the steps between the two main columns vertically, as shown in Figure 12.4.

- A left-to-right flowpath may be used to connect two vertical flowpaths. That is, in response to a flowchart question or decision table positioned in a main flowpath, operators may exit the main flowpath, perform a step or a series of steps, and then enter an adjacent flowpath. The preferred position of symbols to show this organization is two vertical main flowpaths connected by a horizontal flowpath, as shown in Figure 12.5. If the flow of movement entering a rectangular symbol is from the left, then the flowline should exit from the center of the right edge of the symbol (see Figure 12.5). However, long connecting flowpaths should be structured vertically, as shown in Figure 12.6 (Section 6.2, p. 6-2).

- Avoid creating horizontal paths that branch. Branching horizontal paths make flowcharts appear more complex, and they use a great deal of the white space that visually separates the main vertical paths. If a series of steps that connects two main flowpaths contains decision steps, format the sequence vertically between the two main paths as shown in Figure 12.7 (Section 6.2, p. 6-2).

- Position major contingency paths and bypass alternative structures to the right of a main flowpath. Contingency paths and bypass alternatives may be nested within each other, if necessary (see Figure 12.8) (Section 6.2, p. 6-2; Section 6.3.2.1, p. 6-6; Section 6.3.2.2, p. 6-9).

- Format bypass alternative structures with the "Yes" path going straight down and the "No" path going down and to the right of the

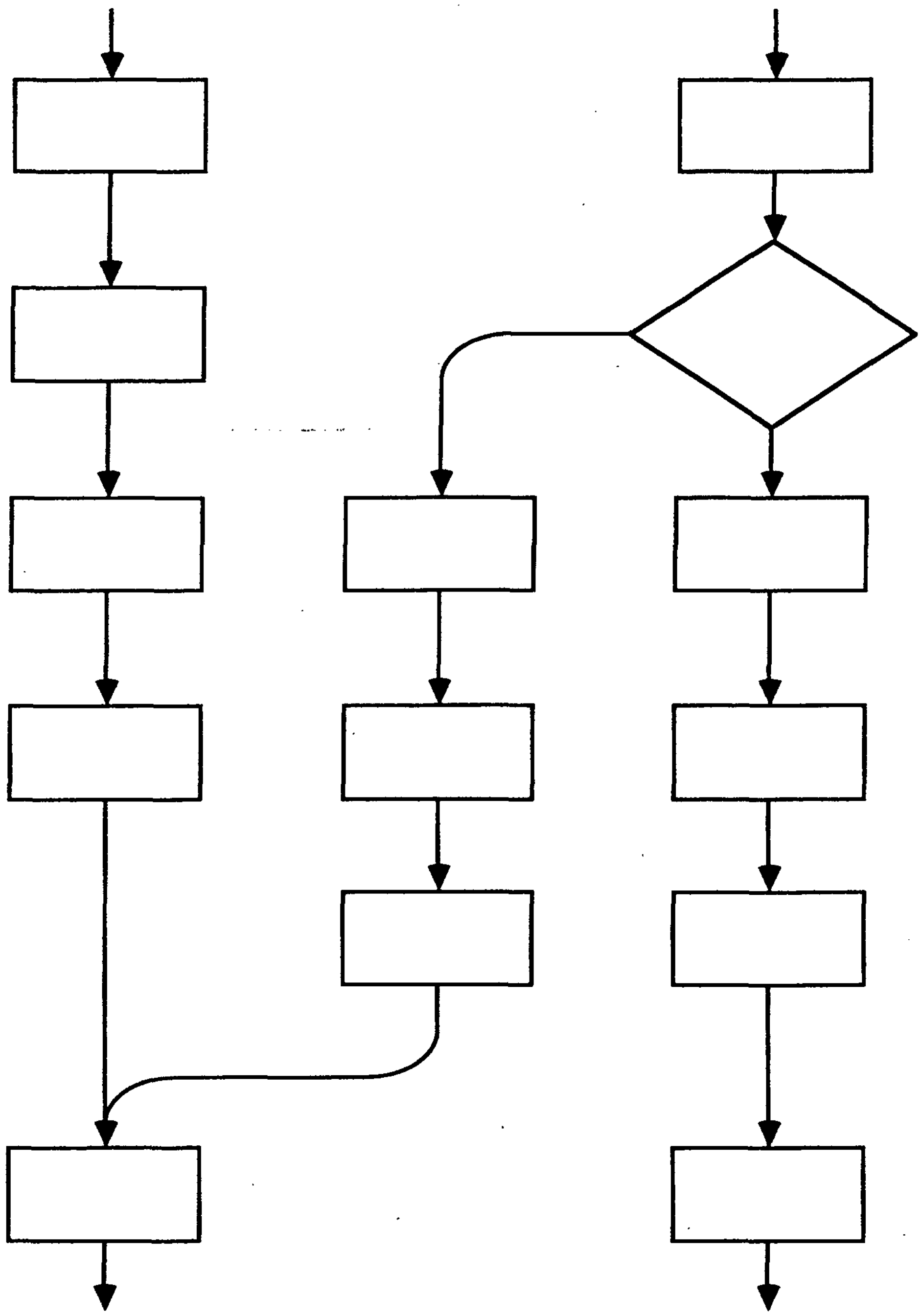


FIGURE 12.4. Vertical Path Used When Right-to-Left Movement Through Several Steps Cannot Be Avoided

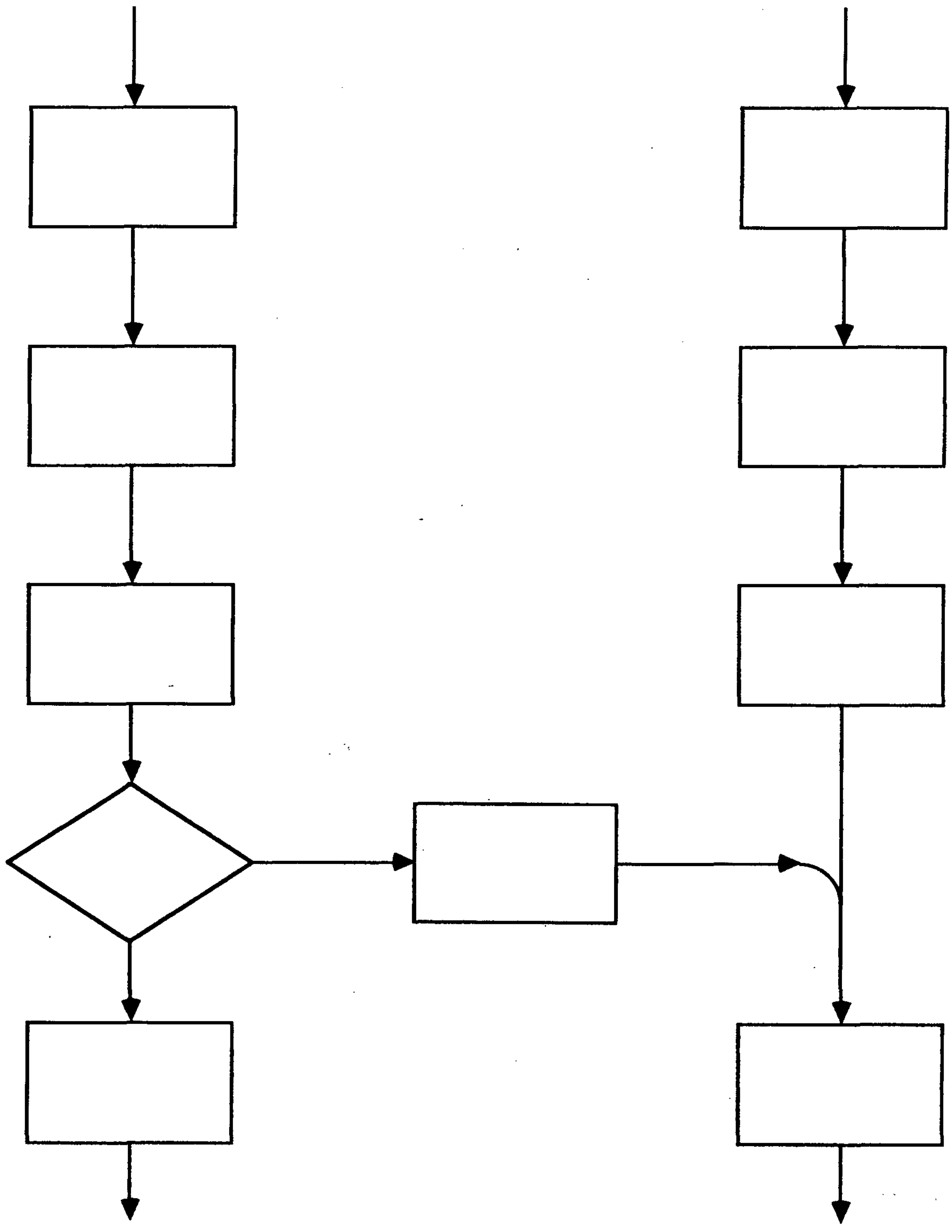


FIGURE 12.5. Left-to-Right Flowpath Connecting Two Vertical Flowpaths

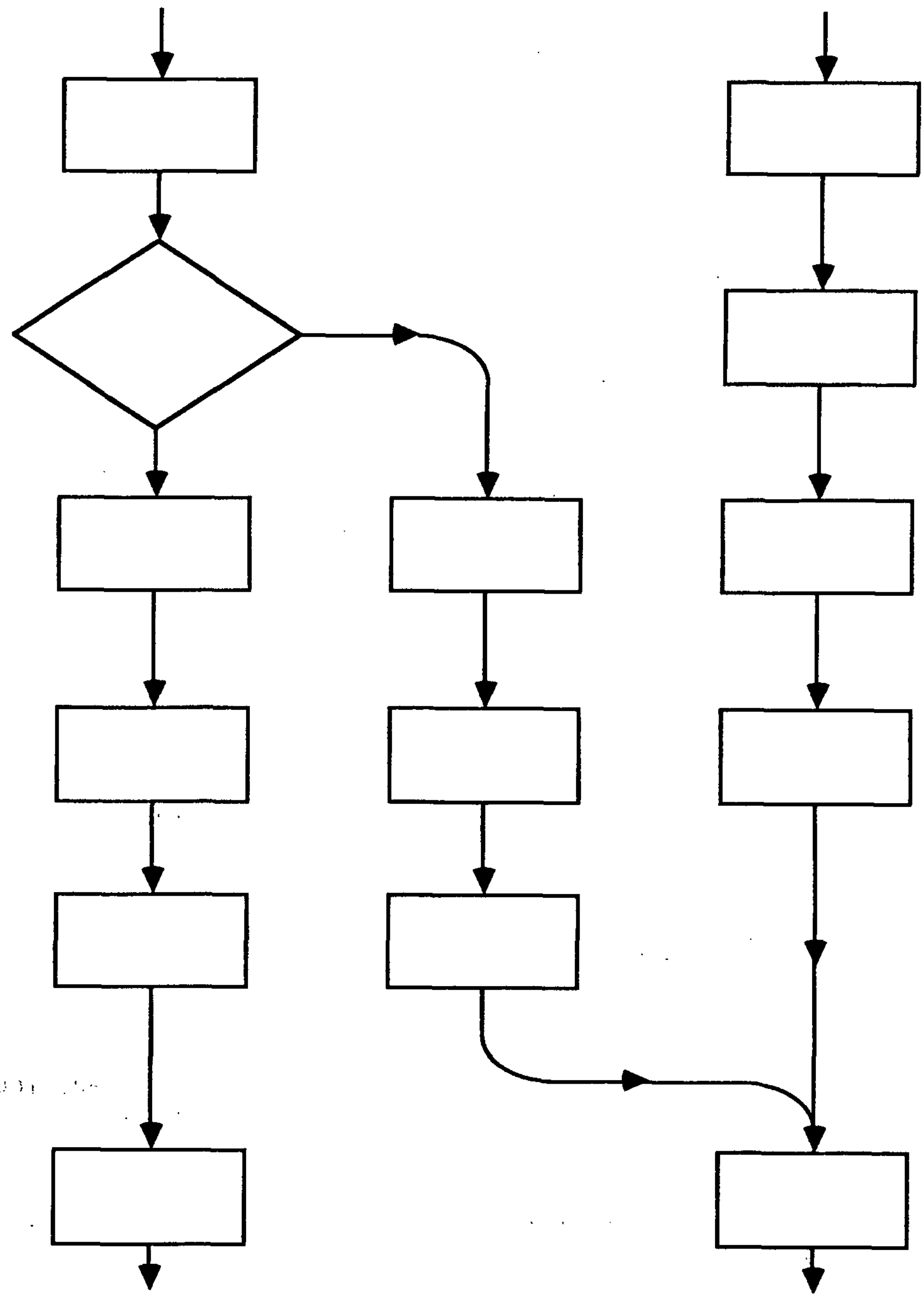


FIGURE 12.6. Vertical Structure for a Long Connecting Flowpath

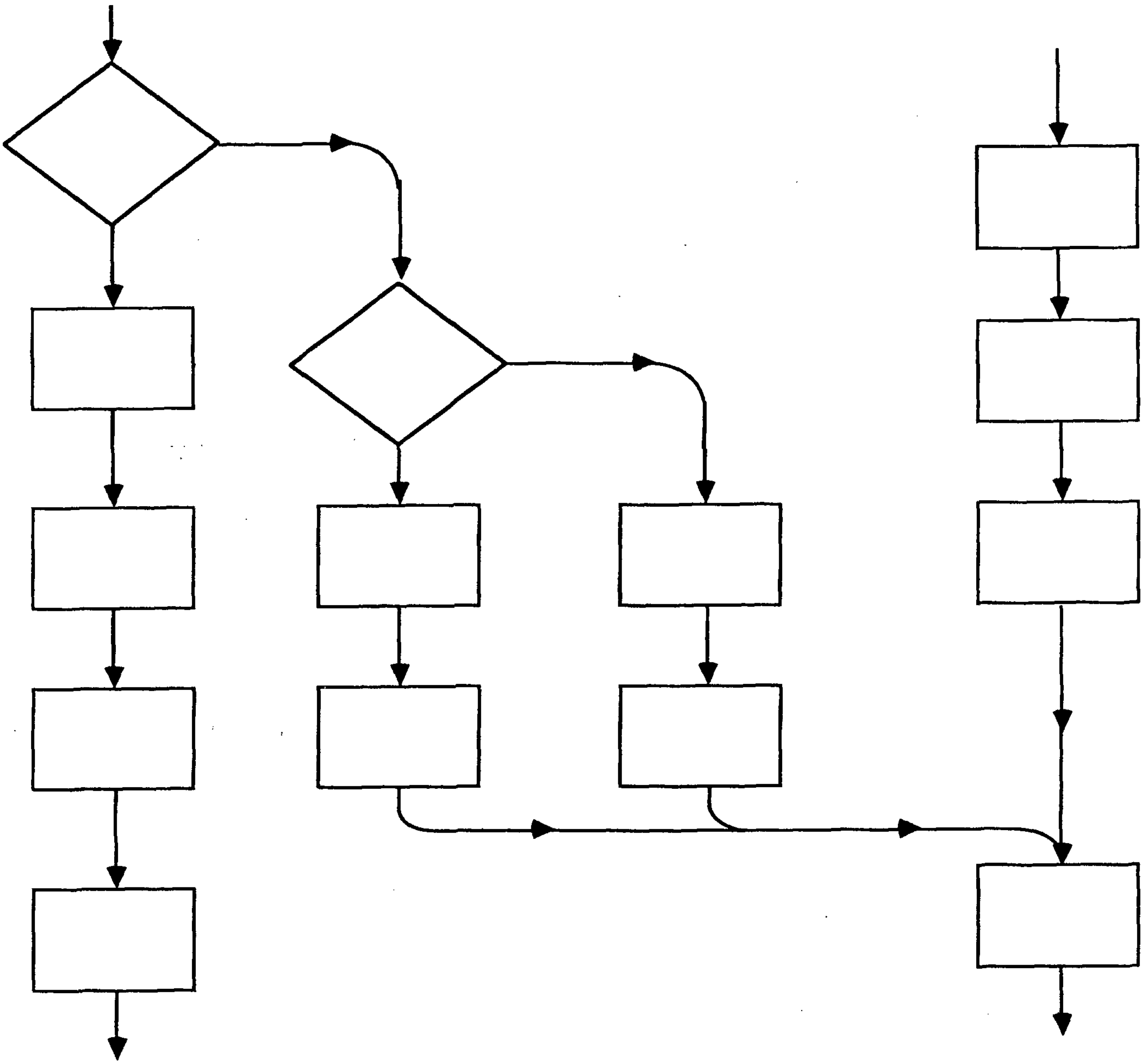


FIGURE 12.7. Vertical Branching Flowpath Connecting Two Main Flowpaths

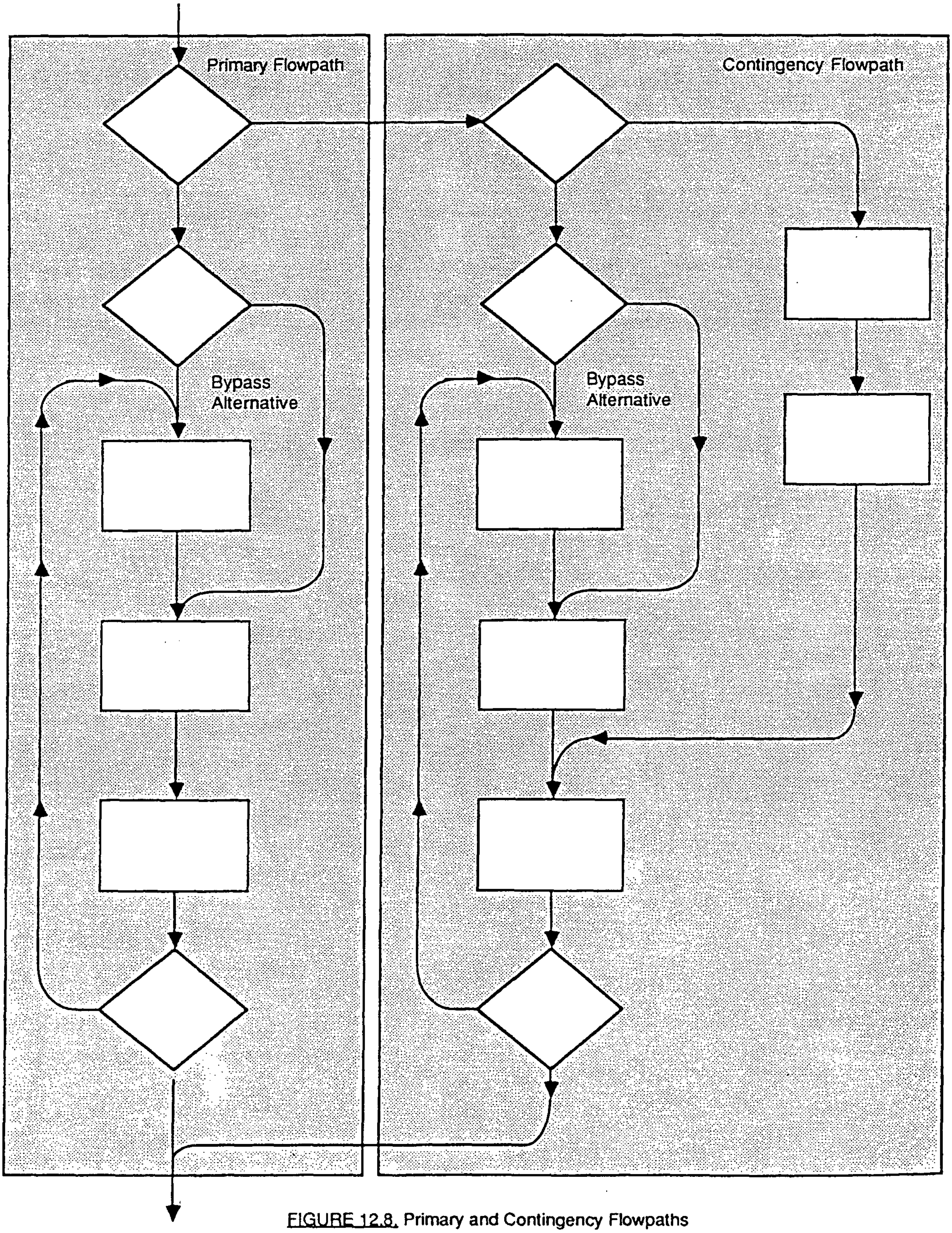


FIGURE 12.8. Primary and Contingency Flowpaths

decision symbol, if possible. Otherwise, position the flowline without steps to the right of the steps that are bypassed (see Figure 12.1 on p. 12-2) (Section 6.3.2.1, p. 6-6; Section 6.3.2.2, p. 6-9).

- In structures that contain a loop (i.e., repetitive structures), draw the looping flowline close to the repeated steps so that it clearly draws a frame around the steps (see Figure 12.9) (Section 6.3.2.3, p. 6-11). However, if any of the steps contain a note, the framing flowline should not separate the note from the flowpath (see Figure 12.10) (Section 6.5.1, p. 6-37).

- Position the looping flowline in a repetitive structure to the left of the flowpath. Ensure that the backward-referencing flowline is closer to the flowpath from which it originates than to any other flowpath on the page (see Figure 12.8 on p. 12-10) (Section 6.3.3.1, p. 6-14; Section 6.3.3.4, p. 6-21).

- When nesting repetitive or bypass alternative structures inside of each other, decrease the distance between the arrows on each flowline, moving out from the centermost framing flowline, as shown in Figure 12.11) (Section 4.3, p. 4-4; Section 6.3.3.4, p. 6-21).

- Use bottom-to-top movement only under two conditions: (1) to indicate a reference to earlier steps in the same flowpath (i.e., a loop), or (2) to indicate that the flowpath is continued at the top of an adjacent column. If a flowline going from one flowpath to another must move upwards, consider repositioning the items in one or both flowpaths so that the movement may be either straight across the page, or across and down. Do not place any steps along a flowpath that is moving up. If none of the arrangements just described are possible, then arrange the flowlines so that the movement first goes up <u>to the steps</u>, then goes down <u>through the steps</u>, and then turns to go <u>up the page</u>, as is shown in Figure 12.12 (Section 5.3.2.1, p. 5-16; Section 6.2, p. 6-2).

- If a bypass alternative structure is used to bypass a long series of steps in a major contingency flowpath, and the main flowpath is continued through multiple columns, consider structuring the column break as shown in Figure 12.13, so that the flow of movement can be made by following a short flowline horizontally across the page from one column to another rather than by following a long flowpath down the first column (Section 6.2, p. 6-2).

- When executing procedures along multiple flowpaths in big-picture flowcharts, it may be essential to coordinate the activities of different operators working in different paths. To ensure coordination, include hold points in the flowcharts that verify the progress of other operators and that instruct the operator to wait, if necessary, for steps to be performed in concurrent paths before continuing (Section 8.1.3.3, p. 8-5).

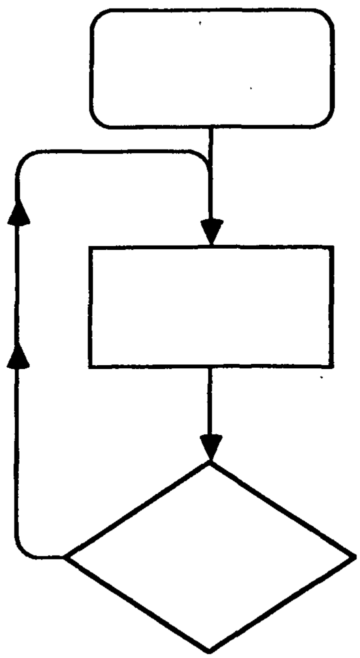


FIGURE 12.9. Looping Flowpath

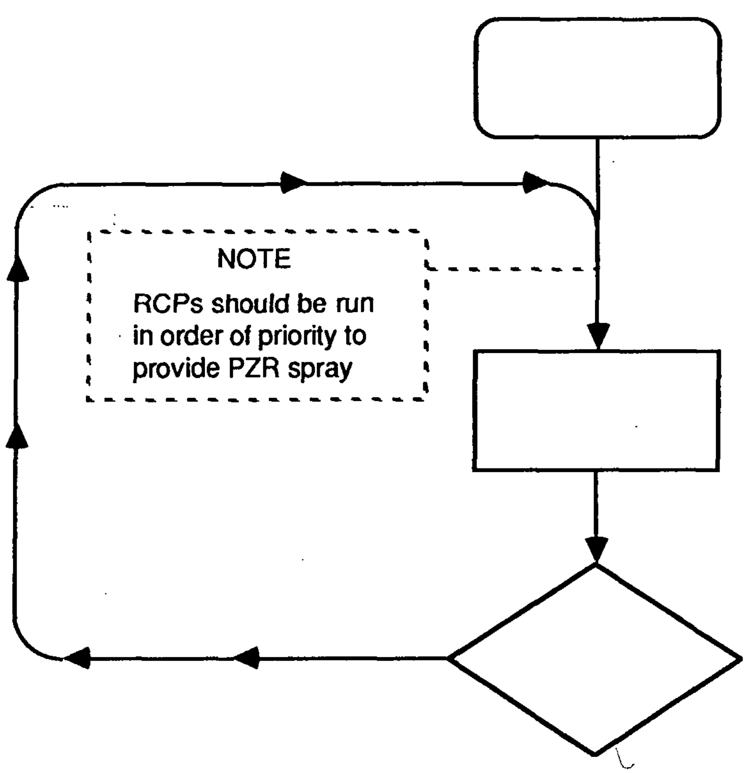


FIGURE 12.10. Looping Flowpath with Note

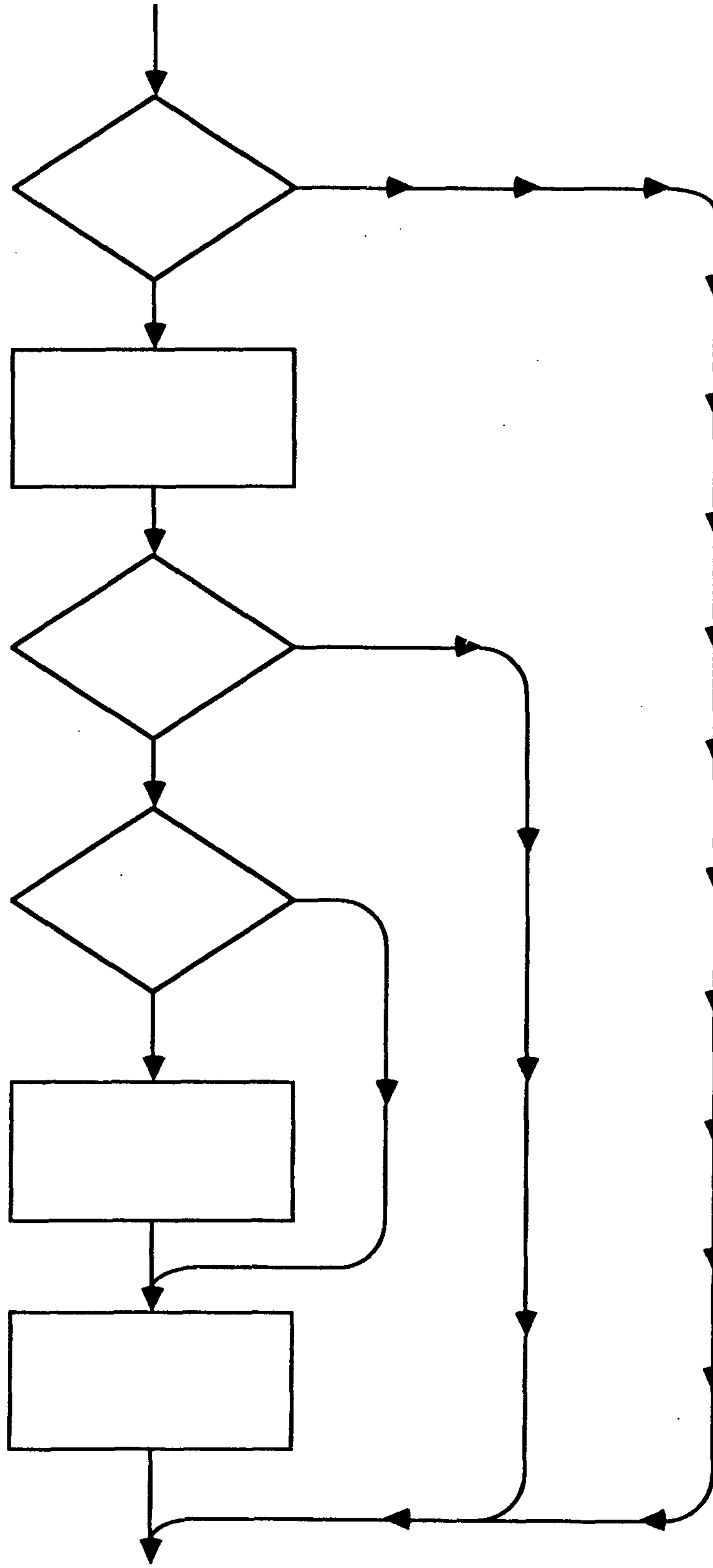


FIGURE 12.11. Spacing of Arrows Used to Differentiate Flowlines

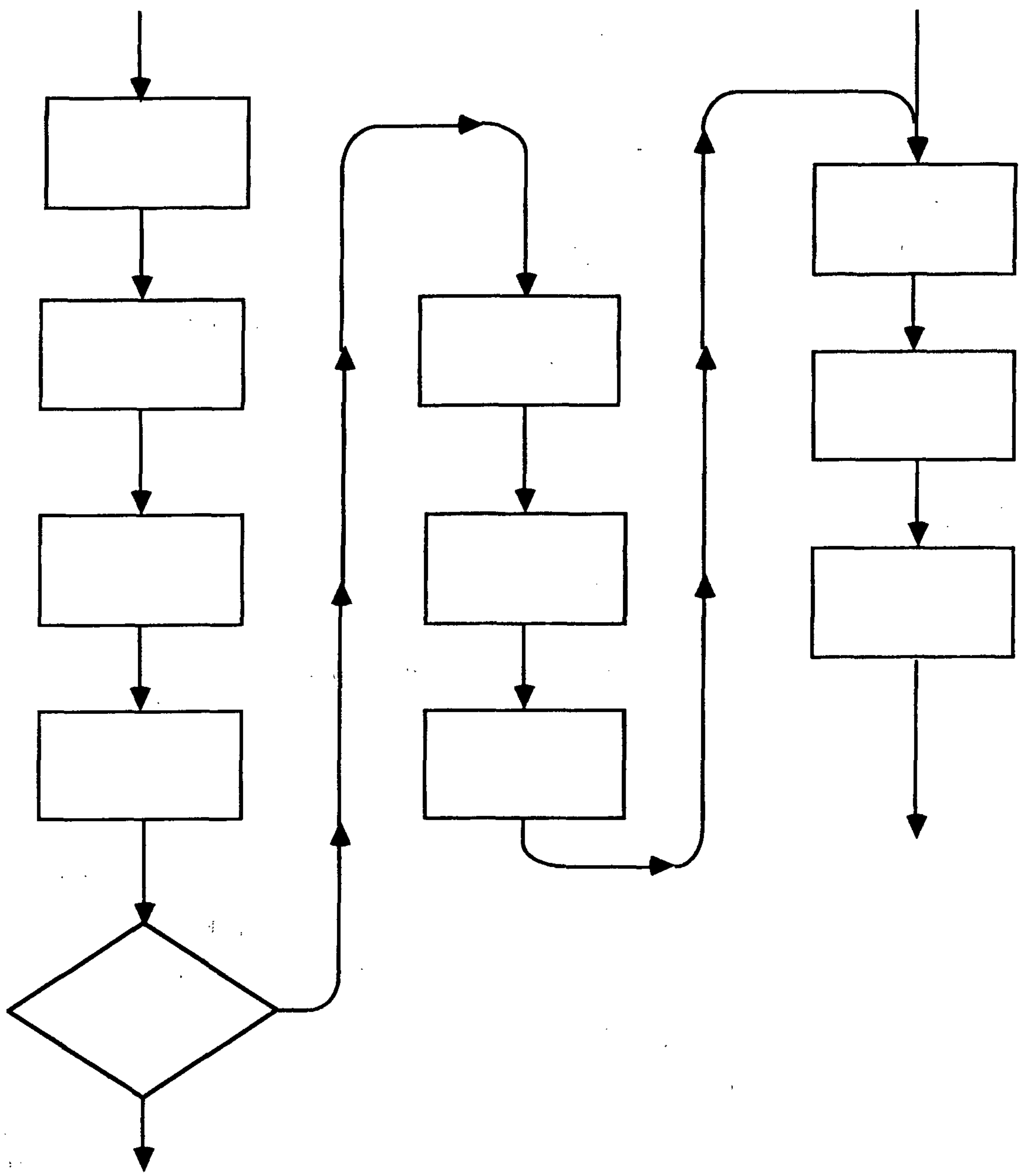


FIGURE 12.12. Vertical Path Used to Avoid Bottom-to-Top Movement Through Steps

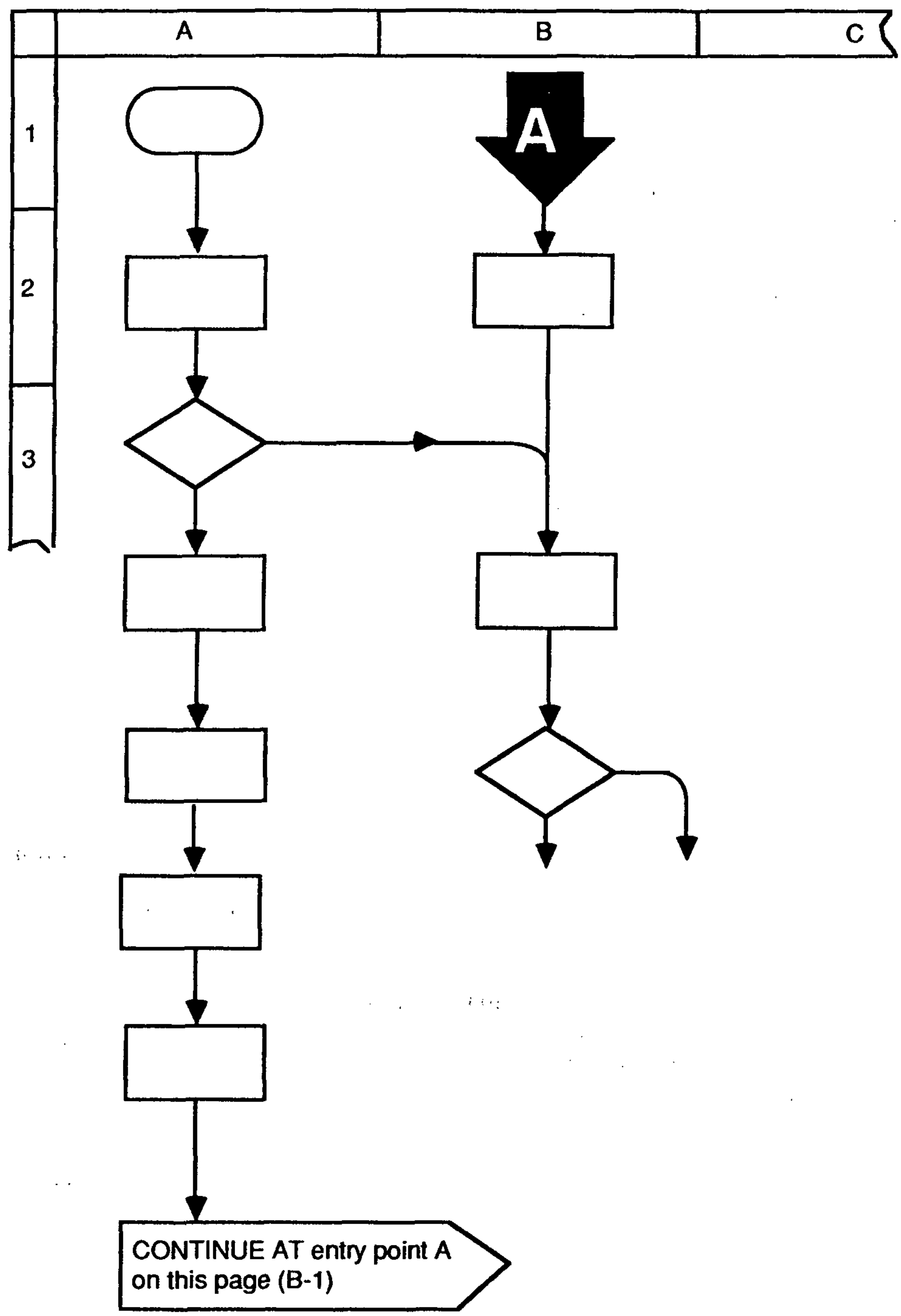


FIGURE 12.13. Horizontal Bypass Alternative Format

12.2 FLOWLINES

The primary method of directing operators' attention through a flowchart is the use of flowlines. When designing flowlines, applying the following techniques will help to ensure that flowlines contrast adequately with the other elements of the flowchart and that the direction of flow described by the flowlines is evident.

- Use solid arrows on flowlines to indicate direction of movement (Section 5.3.2.2, p. 5-17).
- Repeat arrows as necessary to ensure that users do not follow the flowline in the wrong direction, and to ensure that the directions of all flowpaths will be obvious to an operator who is overviewing the procedure. Too many arrows is better than too few, but do not use so many arrows that the background of the flowchart appears cluttered and highly detailed (Section 5.3.2.2, p. 5-17; Section 6.3.3.4, p. 6-21).
- Position arrows at regular intervals so that the arrows along any given flowline create a sense of rhythm (Section 4.4, p. 4-4).
- Merge parallel flowlines that end at the same location into a single flowline (see Figure 12.14) (Section 5.3.2.4, p. 5-20).
- When one flowline merges with another, use a curved line to indicate the direction of the flowline (Section 5.3.2.3, p. 5-17; Section 5.3.2.4, p. 5-20).
- Limit the crossing of flowlines by using connector symbols (Section 5.3.2.6, p. 5-24; Section 5.3.2.7, p. 5-26).
- If crossing flowlines cannot be avoided, place a bubble in the vertical flowline to indicate the intersection of the lines, as shown in Figure 12.15 (Section 5.3.2.7, p. 5-26).
- Round angles in flowlines (Section 5.3.2.3, p. 5-17).
- Avoid unnecessary turns in flowlines (Section 5.3.2.3, p. 5-17).
- Draw flowlines as solid black lines (Section 5.3.2.3, p. 5-17). Flowlines should subtend 3 minutes of arc in good lighting and 4 minutes in poor lighting. To calculate required line widths, use the formula

$$L = 0.00029\ DV$$

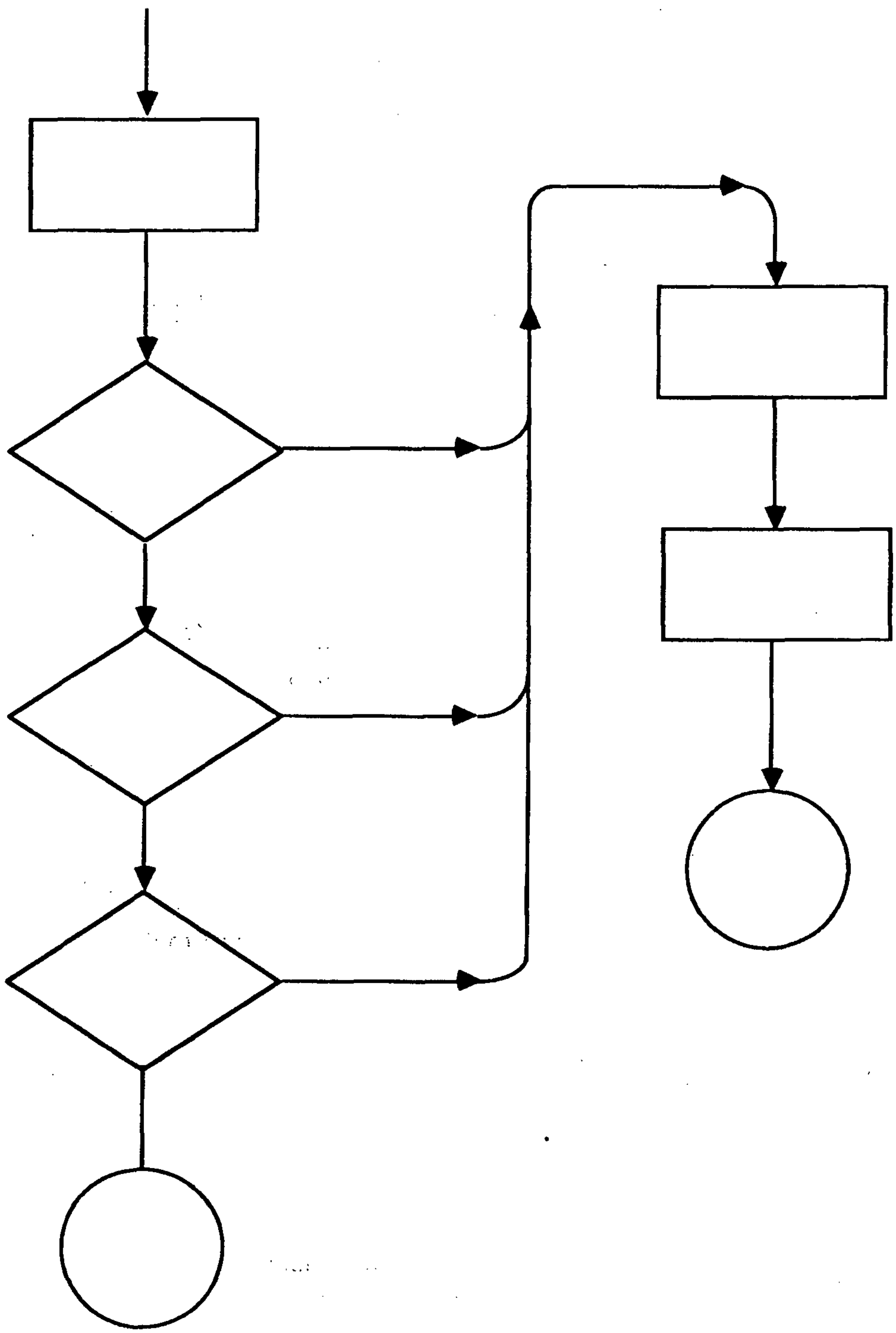


FIGURE 12.14. Merging of Flowlines Going to the Same Destination

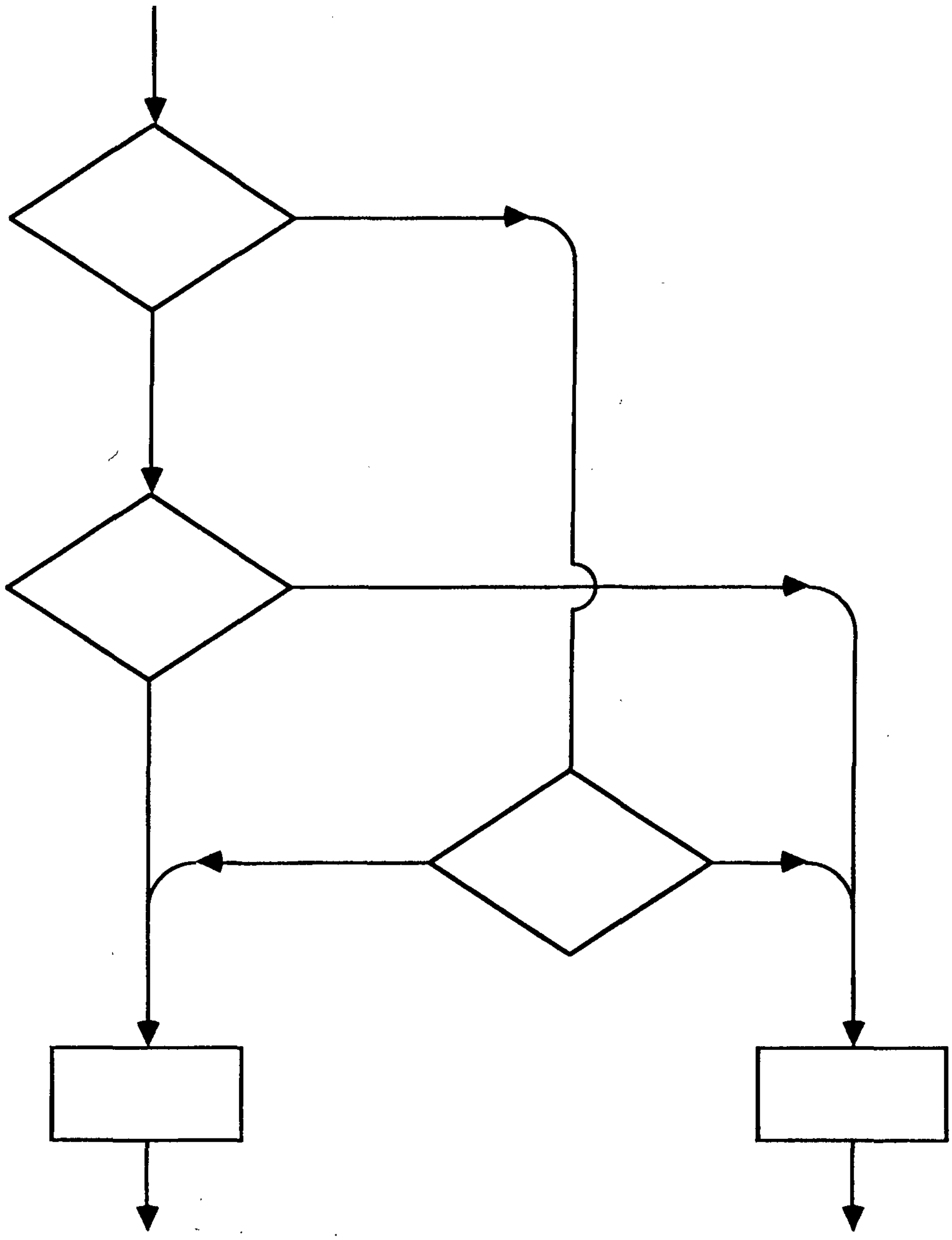


FIGURE 12.15. Crossing of Flowpaths

where L = line width in inches

D = the distance of the viewer's eye from the line on the flowchart

V = the visual angle that should be subtended by the line (either 3 or 4 minutes in this example)

(Section 7.1, p. 7-1).

- If different types of lines are used in a flowchart to convey significant information, ensure that the different line types are easily discriminable. For example, wide, dark flowlines marking the most critical flowpath would be easy to see when the flowchart is overviewed (Section 5.3.2.5, p. 5-20). However, avoid using colors to differentiate between flowlines (Section 5.3.7.4, p. 5-43).

- Keep flowlines short (Section 5.3.2.6, p. 5-24). However, without making the flowchart too large, use longer flowlines to separate logically separate items (Section 5.2.4, p. 5-6). Use shorter flowlines to group related items (Section 5.2.3, p. 5-2).

- Separate parallel flowlines with white space (Section 5.2.4, p. 5-6; Section 5.3.2.4, p. 5-20; Section 6.3.3.4, p. 6-21). White space between parallel flowlines should subtend 30 minutes of arc in good lighting and 40 minutes in poor lighting. To calculate required white space in inches, use the formula

$$WS = 0.00029\ DV$$

where WS = white spaces in inches

D = the distance from the white space on the flowchart

V = the visual angle that should be subtended by the white space (either 30 or 40 minutes in this example)

(Section 7.1, p. 7-1).

- Ensure that symbols emerge as foreground objects, and that the arbitrary shapes created by juxtapositions of flowlines remain in the background (Section 4.7, p. 4-6). To ensure that no figure/ground distortions occur, use these techniques.

  - Do not allow the juxtaposition of flowlines or symbol borders to create a closed box around a flowline label (e.g., a "Yes" or a "No" on flowlines leaving a decision symbol).

  - Ensure that the images created by flowlines and the arrows on the flowlines do not approach the level of visual detail present inside of flowchart symbols.

    * Ensure that juxtapositions of flowlines do not create closed or nearly-closed figures in the background.

* In big-picture flowcharts, do not place flowlines close to the dark lines used in the brackets of override steps because the override brackets will draw operators' attention away from nearby flowlines (Section 5.2.3, p. 5-2).

12.3 REFERENCING AND BRANCHING

Referencing and branching describe non-linear movements in procedures (NUREG-0899, Section 5.2.2, p. 15). Referencing occurs when operators are instructed to concurrently perform two or more steps or series of steps. Branching occurs when operators are instructed to exit one procedure, flowpath, or part of a flowpath and enter another.

Referencing and branching are accomplished in flowcharts either with the use of an appropriate basic structure or with connector symbols. When basic structures and flowlines are used to indicate references and branches, flowcharts can be a superior format for presenting highly branched procedures. The flowlines tie the procedure together visually, so that operators can see the possible paths through the procedures, and the flowlines can be easier to follow than cross-referencing statements in text procedures. When it is impractical to use the basic structures, connector symbols can be used to indicate references and branches. The following techniques can be used to manage referencing and branching.

* Use connector symbols sparingly (Section 5.3.2.6, p. 5-24). If only a few steps are referenced, present them as concurrent action steps in the flowpath (Section 6.4.6, p. 6-35). If the steps to which the operator is branched are few, and he will be returning to the flowpath after performing a series of steps elsewhere, repeat those steps in the flowpath rather than branching to them (NUREG-0899, Section 5.2.2, p. 15).

* Use connector symbols to prevent flowlines from crossing or to branch to or reference another flowchart (Section 5.3.2.6, p. 5-24; Section 5.3.2.7, p. 5-26).

* Use a grid system in the flowchart border to facilitate referencing and branching (Section 5.3.2.6, p. 5-24).

* Use a rectangle with a pointed end as the connector symbol to indicate a branch (Section 5.3.2.6, p. 5-24); use the term "GO TO" to begin the branching statement contained in the symbol (see Figure 12.16).

* Use a rectangle with a pointed end and a pointed bottom as the connector symbol for a reference (Section 5.3.2.6, p. 5-24); use the term "CONCURRENTLY PERFORM" to begin the referencing statement (see Figure 12.17).

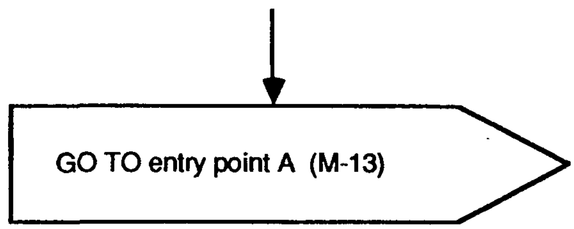


FIGURE 12.16. Branching Symbol

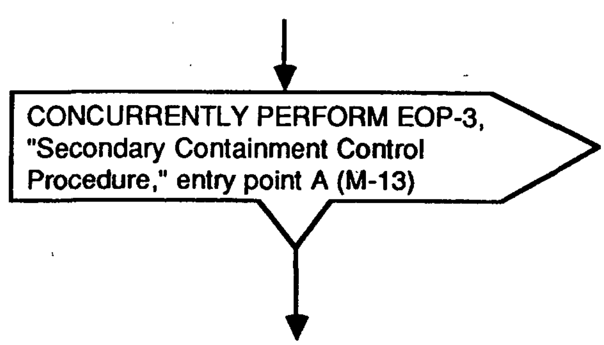


FIGURE 12.17. Referencing Symbol

- For both references and branches, include the procedure name and number, the page number in a multi-page flowchart, and the coordinates and letter of the entry point within the connector symbols (Section 5.3.2.6, p. 5-24).

- Include the words "on this page" in the connector symbol for branches to flowpaths on the same page instead of using a page number (Section 5.3.2.6, p. 5-24).

- Include the procedure name, procedure number, and the number of the referenced step or section when referencing or branching to a text procedure (NUREG-0899, Section 5.2.2, p. 15).

- Draw an entry point (i.e., the point in the flowchart to which the operator is referred by the information in the connector symbol) as a heavy arrow pointing into the flowpath, as shown in Figure 12.18 (Section 5.3.2.6, p. 5-24).

- Place a large, bold letter that identifies the entry point in the entry symbol (Section 5.3.2.6, p. 5-24).

- Shade the arrow so that it appears as one of the darkest items on the page (Section 4.1, p. 4-1; Section 5.2.3, p. 5-2; Section 5.3.2.6, p. 5-24).

- Locate entry points prior to any relevant cautions and notes (Section 6.5.1, p. 6-37) as shown in Figure 12.18.

12.4 COLUMN AND PAGE BREAKS

Column breaks and page breaks in flowcharts are disruptive. The breaks make it difficult for an operator to overview a procedure, and they create opportunities for error. To minimize potential usability problems associated with column and page breaks, use these techniques.

- Do not paginate big-picture flowcharts. If a flowchart is broken into different pages, the big picture is lost (Section 3.2.2, p. 3-22; Section 6.3.3.2, p. 6-14).

- Paginate algorithmic flowcharts only if necessary. Multiple columns on a single page are preferable to multi-page charts. However, a multi-page flowchart is preferable to a visually dense chart on a single page (Section 5.1, p. 5-1; Section 6.2, p. 6-2; Section 6.3.3.2, p. 6-14).

- Position page breaks so that each page represents a logical unit of information and so that a minimum of branching from one page to another is required (NUREG-0899, Section 5.2.2, p. 15; Section 6.3.3.2, p. 6-14).

- In both algorithmic and big-picture flowcharts, when the flowpath encounters a page break or a column break, treat the transition to

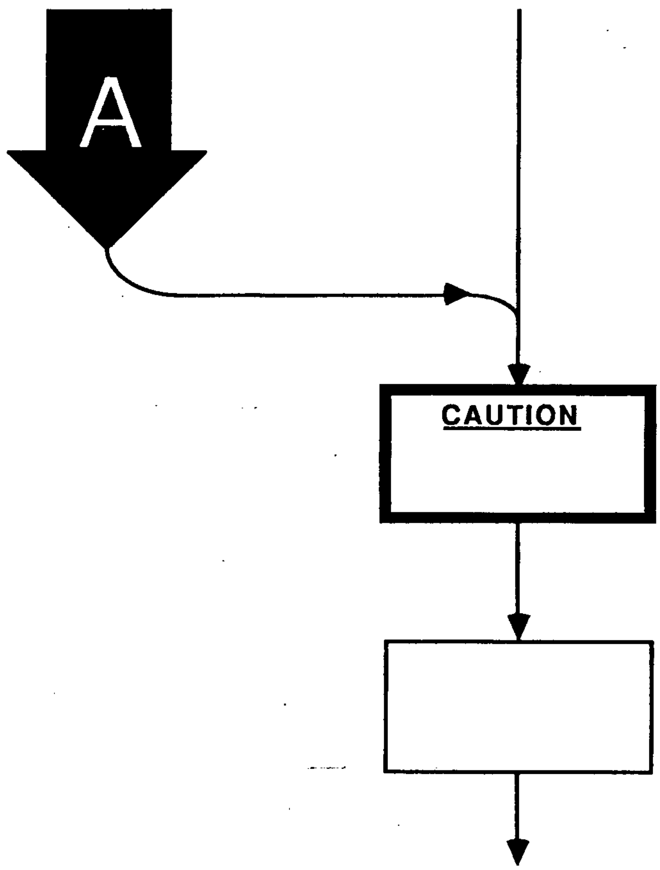


FIGURE 12.18. Entry Point

the next page or column of the same procedure as a branch, but use the term "CONTINUE AT." Provide only the page number, the entry point designation, and the coordinates of the entry point in the branch statement within the connector symbol. Because a CONTINUE AT branch will not send operators to other procedures, do not include the procedure name or number (Section 5.3.2.6, p. 5-24; Section 6.3.3.2, p. 6-14).

- Limit column breaks in big-picture flowcharts. If only one of the major flowpaths is too long to be presented as a single vertical flowpath, position this flowpath and its continuation as the two columns farthest right on the page. The distance between these two columns should be wide enough to visually separate the columns, but narrower than the spaces between the different flowpaths (Section 6.3.3.2, p. 6-14).

- Page breaks and column breaks should, if at all possible, only violate a single flowline. Place the break after an action step rather than after a decision step (Section 6.3.3.2, p. 6-14).

- Avoid breaking action steps in series of closely-related actions (Section 5.3.2.6, p. 5-24; Section 6.3.3.2, p. 6-14).

- Do not position a break through a loop (Section 5.3.2.6, p. 5-24; Section 6.3.3.2, p. 6-14; Section 6.4.1, p. 6-24).

- If the transition at a page break is to another procedure, the transition is a branch. Use the term "GO TO" to indicate the branch. Include the procedure number, title, and entry location in the branching statement (Section 5.3.2.6, p. 5-24).

13.0 FLOWCHART CONTENTS

This section addresses the contents of flowchart EOPs. Like text EOPs, flowchart EOPs will typically contain entry conditions and immediate operator actions, action steps of various types, decision steps, cautions, notes, figures, tables, page identification information, references to plant hardware, and placekeeping aids methods for presenting these types of information in flowchart EOPs are discussed in this section.

13.1 ENTRY CONDITIONS AND IMMEDIATE OPERATOR ACTIONS

One of the best uses of the algorithmic flowchart format is to assist operators in deciding which procedure to follow at the initiation of an emergency event, as this is a process that may require many decisions. The use of basic flowchart structures can simplify the often complex problem of establishing whether or not a procedure should be executed. As well as consisting of a set of plant indications, flowchart entry conditions may consist of a reference from another procedure. To ensure that the beginning of a flowchart can be easily found, the entry points of all flowcharts in a flowchart set should be clearly formatted and consistently positioned on the flowchart sheets.

Use these techniques when formatting entry conditions and immediate operator actions.

- Position entry conditions at a consistent location on all flowcharts (Section 4.5, p. 4-4; Section 5.3.1, p. 5-13). Because movement through the flowchart will be downward and to the right, position the entry point either in the upper left hand corner of the flowchart or at the top center of the flowchart (Section 5.3.2.1, p. 5-16; Section 6.2, p. 6-2).

- Use either a rectangle with rounded corners or an elongated oval to indicate the entry point of the flowchart. These symbol shapes are similar to the circle, traditionally used as an entry symbol for flowcharts, and they accommodate text more efficiently than does a circle (Section 5.3.3, p. 5-26).

- In a flowchart that is only entered by a reference from another procedure, the conditions that initiated the use of the flowchart may be summarized within the entry symbol (NUREG-0899, Section 5.4.4, p. 17).

- Follow entry conditions with the immediate operator actions (if any) that the operators have memorized and may have already taken before entering the flowchart (NUREG-0899, Section 5.4.6, p. 17).

- Use decision and action symbols to present immediate operator actions (Section 5.3.1, p. 5-13; Section 6.4.1, p. 6-24, Section 6.4.2, p. 6-24).

13.2 ACTION STEPS

Action steps are instructions to operators. In big-picture flowcharts, closely-related steps or higher-level steps with substeps can be grouped together in a segmented action symbol. Such techniques would defeat the purpose of an algorithmic flowchart, however, since algorithmic flowcharts are intended to simplify decision processes by breaking the process into small steps.

Use these techniques for presenting action steps.

- Enclose action steps in a rectangle (Section 5.3.3, p. 5-26; Section 6.4.1, p. 6-24).

- To promote a clear column structure in flowcharts, keep the width of all rectangles constant and consistent with the width of the decision symbols (see Figure 13.1) (Section 5.2.4, p. 5-6). The length of action symbols can be increased as needed to accommodate text (Section 5.3.5, p. 5-36; Section 6.4.1, p. 6-24).

- Ensure that action steps are complete on one page and, in multi-column flowcharts, are not broken between columns (NUREG-0899, Section 5.5.2, p. 8).

- Write action steps in the imperative mode (NUREG-0899, Section 5.3.6, p. 21).

- Structure action steps (1) to minimize physical interference between control room personnel, (2) to avoid unintentional duplication of tasks, (3) to minimize the movement of personnel around the control room, (4) to be consistent with the roles and responsibilities of operators, (5) to enable the supervisor to follow staff actions and monitor plant status, and (6) to be executed by the minimum control room staff, as defined in the plant technical specifications (Section 6.1, p. 6-1; NUREG-0899, Section 5.3.8, p. 25).

- In algorithmic flowcharts, place only one action or two closely-related actions inside of each symbol. An example of closely related actions is "Stop diesel generators and place in standby" (Section 6.4.1, p. 6-24).

- In big-picture flowcharts, place only one action or two closely-related actions inside of each symbol, except under the two conditions listed below.

    - Use divided boxes as a grouping technique so that operators can associate logically related steps, as shown in Figure 13.2 (Section 3.2.2, p. 3-22).

    - Higher-level steps and substeps can be placed within a single action symbol when it is especially important that operators understand why a set of actions is being performed. State the

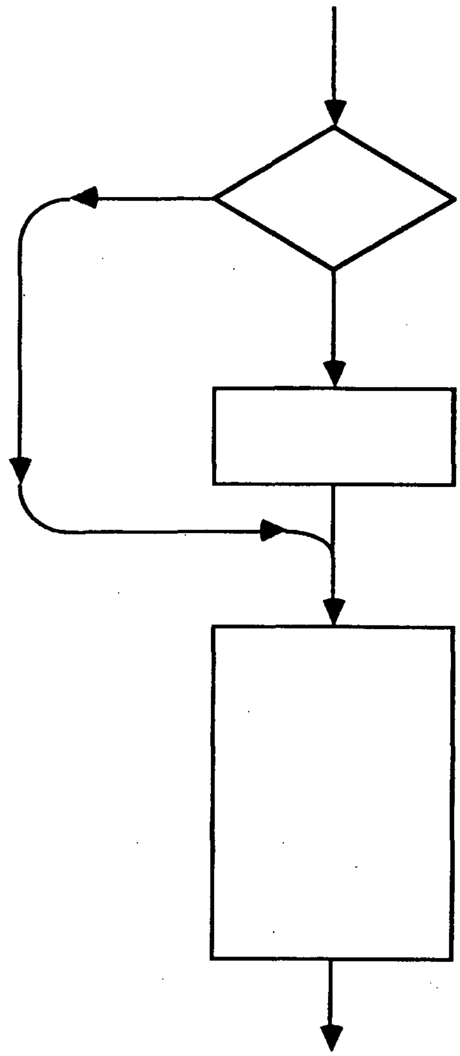


FIGURE 13.1. Relative Symbol Sizes

Maintain at least one of the following conditions:

- Drywell and torus hydrogen concentrations below 6%
- Drywell and torus oxygen concentrations below 5%

<u>IF</u> torus water level is below 300 in.,
<u>THEN</u> initiate supression chamber sprays

<u>IF</u> torus water level is below 183 in.
<u>AND</u> drywell pressure and temperature are below the DSIL,
<u>THEN:</u>

- Shut down the reactor circulation pumps
- Shut down the drywell cooling fans
- Initiate drywell sprays

<u>FIGURE 13.2.</u> Associated Steps in a Divided Box

reason for performing the actions (the higher-level step) and then indent and bullet the substeps that state which actions are to be performed (Section 3.1.3.3, p. 3-21; Section 3.2.2, p. 3-22).

13.2.1 Verification Steps

Verification steps are used to ensure that the objective(s) of a task or a sequence of actions has been met. A verification step consists of a decision step and a closely-related action step. That is, operators are directed to check to see if something has happened, and, if it has not, they are typically required to initiate the action manually. The techniques described below provide a method for presenting verification steps which is clear and which is more space efficient than presenting each verification step as a decision step and an action step.

- Present the verification step as an action beginning with the action verb "verify." Do not use any other action verb, such as "check" (NUREG-0899, Section 5.2.7, p. 22; Section 6.4.3, p. 6-32).

- Ensure that operators are trained that the verb "verify" means that they should check for something and, if necessary, manually initiate it (Section 6.4.3, p. 6-32).

- In big-picture flowcharts, use hold steps to verify the progress in other flowpaths. Example: "WHEN RPV pressure is stable, THEN continue in this path" (Section 6.6, p. 6-41).

13.2.2 Nonsequential Steps

Nonsequential steps require that an action be carried out at various intervals throughout a procedure or that two or more actions be performed concurrently (NUREG-0899, Section 5.7.3, p. 23). Depending upon the content of the step, it may be formatted as either a decision step or an action step. There are four types of nonsequential steps in EOPs: (1) steps of continuous applicability, (2) steps that are repeated at intervals, (3) time-dependent steps, and (4) concurrent steps. All of these steps can potentially make procedures, especially algorithmic flowcharts, difficult to follow.

13.2.2.1 Steps of Continuous Applicability

Some steps apply at anytime in the procedure that particular conditions are met. These are steps of continuous applicability.

- Ensure that the text of the step indicates all of the conditions under which the step applies (Section 6.4.4, p. 6-32).

- Limit the use of steps of continuous applicability in algorithmic flowcharts. If these steps are necessary, they should be presented in one of the following ways: (1) Repeat the step throughout the flowchart at the points at which it is likely to apply, or (2) present the step in the flowchart at the first point at which it applies and then repeat it in a box in one corner of the flowchart sheet as a reminder to operators (Section 6.4.4, p. 6-32).

- Mark steps of continuous applicability with one or more dissociative variable, such as position, size, or value (Section 5.2.3, p. 5-2; Section 6.4.4, p. 6-32).

- Indicate the applicability of the step with dark brackets that enclose the steps to which it applies, if possible (Section 6.4.4, p. 6-32). Do not use this convention if it cannot be applied consistently throughout the flowchart (Section 4.5, p. 4-4).

- If these steps are presented together in a box located on the edge of a flowchart sheet, ensure that operators are trained to refer to the box frequently throughout the course of performing the procedure (Section 8.2, p. 8-5).

- In big-picture flowcharts, present steps of continuous applicability in the same manner as override steps; that is, so that a heavy border extends below the text of the nonsequential step and that this border brackets the steps to which the nonsequential step applies, as shown in Figure 13.3 (Section 6.4.4, p. 6-32).

13.2.2.2 Recurrent Steps

Recurrent steps are nonsequential steps that require operators to repeatedly perform an action or to monitor a plant parameter (NUREG-0899, Section 5.7.5, p. 23). Override steps, which require operators to continually monitor a series of plant parameters, are recurrent steps.

- Ensure that the text of the recurrent step indicates the conditions under which the recurrent step should be performed (Section 6.4.4, p. 6-32).

- In algorithmic flowcharts, repeat the recurrent step wherever it is necessary. Do not require operators to remember recurrent steps. Format the recurrent step as an action or decision step, depending upon the content of the step (Section 6.4.4, p. 6-32).

- In big-picture flowcharts, present recurrent steps as override steps; that is, so that a heavy border extends below the text of the recurrent step and that this border brackets the steps to which the recurrent step applies (Section 5.3.3, p. 5-26).

13.2.2.3 Time-Dependent Steps

Time-dependent steps are nonsequential steps that require operators to take an action at some point of time in the future (NUREG-0899, Section 5.7.6, p. 23). For example, an operator might be required to close a valve thirty minutes after opening it.

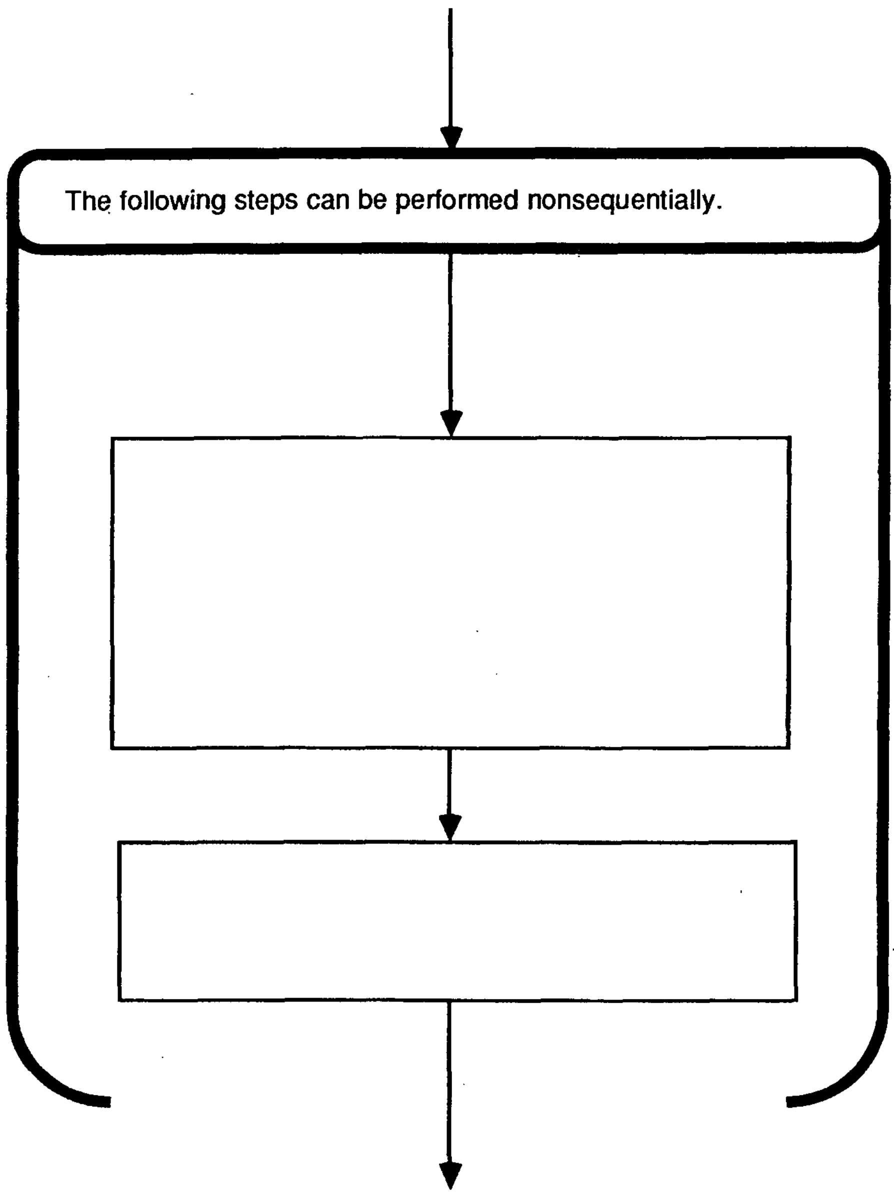


FIGURE 13.3. Nonsequential Steps in a Big-Picture Flowchart

- Present time-dependent steps at the point in the flowchart that "starts the clock" (Section 6.4.4, p. 6-32).

- So that operators can keep track of when time-dependent steps should be performed, include a space for operators to note the time at which they must take the action (Section 6.4.4, p. 6-32).

- Limit the use of time-dependent steps in algorithmic flowcharts. If a time-dependent step is necessary,

  - Repeat the time-dependent step in a box in one corner of the flowchart with other nonsequential steps (Section 6.4.4, p. 6-32).

  - Ensure that operators are trained to refer to the box (Section 8.2, p. 8-5).

13.2.2.4 Concurrent Steps

Concurrent steps are those that have to be performed at the same time (NUREG-0899, Section 5.7.7, p. 23). Big-picture flowcharts make extensive use of concurrent steps because the basic idea behind big-picture flowcharts is to show concurrent flowpaths on the same page. Concurrent steps violate the basic principles of algorithmic flowcharts. Performing tasks in multiple paths may force the operator to make multiple decisions simultaneously rather than move through the algorithm in a sequential manner.

- Minimize the use of concurrent steps (Section 6.4.6, p. 6-35). In both big-picture and algorithmic flowcharts, the number of different courses of action that must be taken at one time greatly affects the complexity of a procedure (Section 3.2.3, p. 3-24). The graphics of the flowchart will only provide a useful overview of the procedure if all concurrent paths are formatted so that they are readily visible (Section 6.3.3.3, p. 6-19; Section 6.4.6, p. 6-35).

- In big-picture flowcharts, present multiple flowpaths in parallel columns on a single, large sheet of paper. If possible, construct the flowchart so that all concurrent paths begin at the same horizontal level of the flowchart, near the top of the page (Section 3.2.2, p. 3-22).

  - Use the entry conditions step to direct operators into all of these major flowpaths (Section 3.2.3, p. 3-24).

  - Label each concurrent path in a big-picture flowchart to indicate the purpose of the steps in the path (Section 3.1.3.3, p. 3-21).

  - Train operators to monitor progress through all relevant paths concurrently (Section 8.2, p. 8-5).

- When presenting concurrent steps with in the body of the flowchart, format concurrent steps along two parallel adjacent flowpaths. Since this format typically indicates an alternative structure, use the following techniques to clearly indicate that the steps in <u>both</u> columns are to be performed.

  - Use branches out of an action step symbol to indicate concurrent steps in algorithmic flowcharts as shown in Figure 13.4 (Section 6.4.6, p. 6-35).

  - Use the action step that precedes the concurrent steps to instruct the operator to "Perform the following steps concurrently" (Section 6.4.6, p. 6-35).

  - Draw one flowline out of the bottom of the step that precedes the concurrent steps and split it into two flowlines that enter the centers of the concurrent steps (Section 6.4.6, p. 6-35).

  - Format the concurrent steps in action step symbols that are placed side-by-side and centered under the preceding step that refers to them (Section 6.4.6, p. 6-35).

  - Merge the flowlines that leave the concurrent steps before they enter the next action step symbol in the flowpath (Section 6.4.6, p. 6-35).

13.2.3 <u>Equally Acceptable Steps</u>

Equally acceptable steps are used when there is more than one action that may be taken in a certain situation, and these actions are equally correct (NUREG-0899, Section 5.7.4, p. 23). That is, there may be two or more methods to accomplish a given objective.

- Because space is at a premium in flowcharts and because operators should not be required to make unnecessary decisions, avoid presenting equally acceptable steps. Whenever possible, present only one of the equally acceptable actions. Format the option as a typical action step (Section 6.4.5, p. 6-34).

- If there are likely to be conditions under which one of the alternative actions is preferable, format the step as a decision step (Section 6.4.2, p. 6-24).

13.2.4 <u>Hold Steps</u>

Hold steps require operators to wait until certain conditions exist before continuing on in the procedure. Although they may be used in algorithmic flowcharts, they are more common in big-picture flowcharts.

- Do not format hold steps as a loop containing only a decision step as shown in Figure 13.5 (Section 6.3.3.3, p. 6-19).

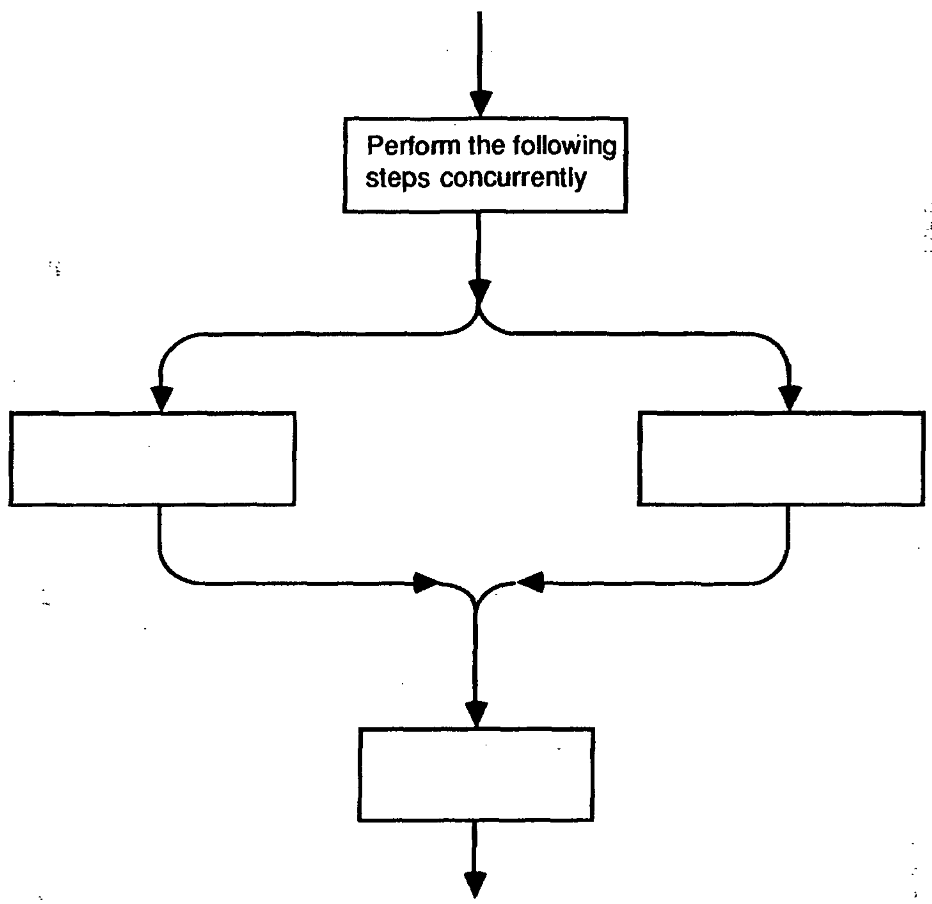


FIGURE 13.4. Concurrent Actions in an Algorithmic Flowchart

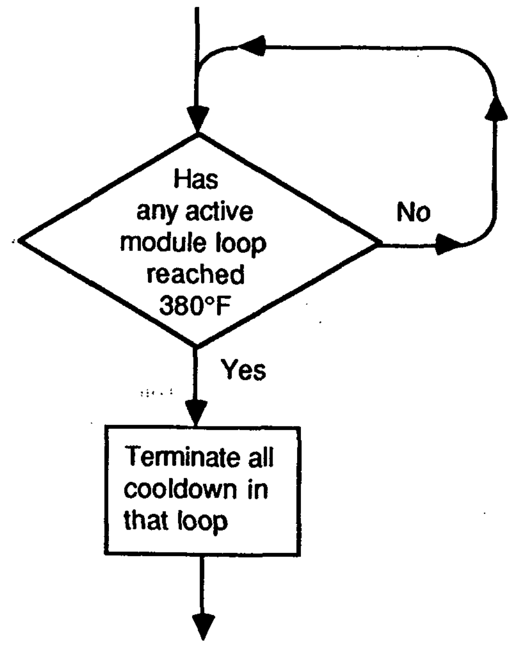


FIGURE 13.5. Improper Formatting of a Repetitive Structure That Contains Only One Decision and No Actions

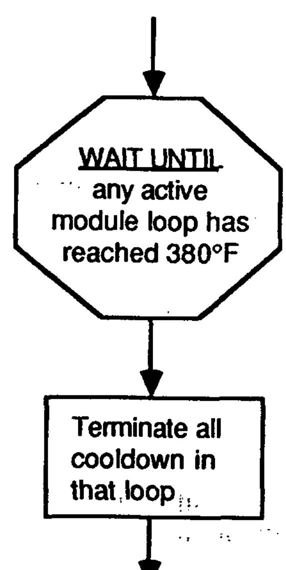


FIGURE 13.6. Proper Use of a Hold Symbol to Present the Steps in Figure 13.5

- Format hold statements as a WHEN..., THEN or a WAIT UNTIL logic statement, placed in an octagon shaped symbol as shown in Figure 13.6 (Section 6.3.3.3, p. 6-19).

13.3 DECISION STEPS

When reaching a decision point, the operator is required to make a decision and to follow the appropriate flowpath, based on plant conditions. There are three formats appropriate for presenting decision steps in flowchart EOPs: (1) structures based upon flowchart decision symbols, (2) decision tables, or (3) logic statements. Switching back and forth among these formats will be more difficult for operators than simply following one format throughout a flowchart. Therefore flowchart designers should choose one of these formats and use it as consistently as possible.

13.3.1 Selecting a Decision Step Format

The following criteria describe when each method of presenting decision steps is suitable.

- Use decision tables only when the decision table can present decision criteria more concisely and clearly than a series of decision symbols (see Figure 13.7), and in situations where the actions dictated by the table do not affect the decision being made (Section 6.4.2.3, p. 6-26).

- Do not use decision tables when alternative actions include long or complex courses of action. In such cases, there is typically inadequate space within the individual cells of the table to provide complete instructions (Section 6.4.2.3, p. 6-26).

- Use basic structures to present decisions in algorithmic flowcharts. The strength of algorithmic flowcharts as decision aids lies in the fact that the flowlines created at branch points lead the operators through the appropriate actions and subsequent decisions, simplifying the process of moving through the procedure (Section 6.4.2.1, p. 6-25).

- In algorithmic flowcharts, use basic structures for diagnostic steps (NUREG-0899, Section 5.7.8, p. 23; Section 3.1.2, p. 3-14).

- In big-picture flowcharts, use logic statements, decision tables, or special decision symbols for diagnostic steps (NUREG-0899, Section 5.7.8, p. 23; Section 3.2.3, p. 3-24).

- In big-picture flowcharts, limit the use of diamond-shaped decision symbols. Because big-picture flowcharts are a hybrid of text procedures and flowchart graphic techniques, it can be practical to include decision steps presented as logic statements in modified action or decision symbols (see Figures 13.8 and 13.9). These symbols use space more efficiently than diamond-shaped symbols (Section 6.4.2.2, p. 6-25).

Control RCS pressure and charging			
PZR Level	Ruptured S/G Level		
	Stable or Increasing	Decreasing	Off-Scale High
Less than 20%	• Increase charging flow. • Depressurize RCS.	Increase charging flow.	• Increase charging flow • Maintain RCS pressure equal to S/G pressure.
Between 20-50%	Depressurize RCS.	Energize PZR heaters.	Maintain RCS pressure equal to S/G pressure.
Between 50-75%	• Decrease charging flow. • Depressurize RCS.	Energize PZR heaters.	Maintain RCS pressure equal to S/G pressure.
Greater than 75%	Decrease charging flow.	Energize PZR heaters.	Maintain RCS pressure equal to S/G pressure.

FIGURE 13.7. Appropriate Use of a Decision Table

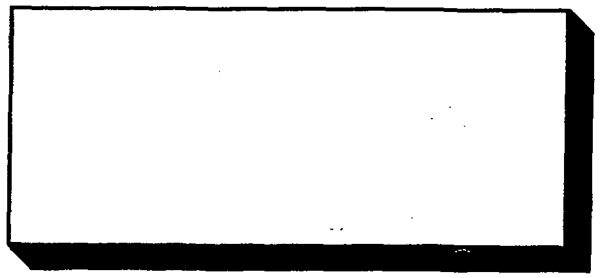


FIGURE 13.8. Shading Used to Show a Decision Symbol

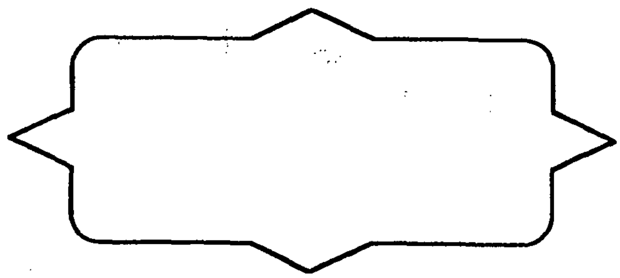


FIGURE 13.9. Diamond-Shaped Decision Symbol with Embedded Rectangle

13.3.2 Using Decision Symbols to Present Decision Steps

Decision steps can be constructed using structures based on flowchart decision symbols. Such steps should use the basic structures described in Section 12.1 of this volume.

- Consider structuring the flowchart so that all "yes" paths and all "no" paths exit decision symbols in a consistent fashion. For example, the flowchart could be constructed so that all "yes" paths exit from the bottoms of decision symbols and so that all "no" paths exit from the right side of decision symbols (Section 6.4.2.1, p. 6-25). Do not follow this convention if it requires the construction of awkward questions, such as "Has the reactor not tripped?" If this convention cannot be applied consistently, mix the directions of exit from decision symbols rather than having most "yes" paths exit downward, and only one or two "No" paths exiting from the bottom of the symbol.

- Ensure that the questions asked in decision symbols always reflect the full meaning of the antecedent condition in the logic statement provided in the generic technical guidelines. For example, the owners' group generic technical guidelines could pose the condition "IF RPV pressure is rising, THEN . . ." In order to establish Yes/No path exit point consistency, it could be necessary to ask the negative of this question ("Is RPV pressure not rising?"). If this question is restructured to remove the word "not," the restructured question must address both of the possible conditions under which the pressure would not be rising, i.e., "Is RPV pressure stable or falling?" (Section 6.3.2.1, p. 6-6).

- If possible, find a positive wording for all questions in decision steps. For example, ask "Are MSIVs closed," rather than "Are MSIVs not open" (Section 6.4.2.1, p. 6-25).

- In addition to labeling exits from decision symbols with "Yes" and "No" where appropriate, restate the condition to be met, if possible, on the flowline (Section 6.3.2.1, p. 6-6).

- If a case structure (i.e., more than two flowpaths leave the symbol) is used, ensure that all possible answers to the question are addressed. If a binary decision structure is inappropriate, consider using a decision table rather than a case structure (Section 6.3.2.1, p. 6-6; Section 6.4.2.3, p. 6-26).

- In algorithmic flowcharts, structure the decision points as alternative, repetitive, or divergent basic structures or their variants (Section 6.3; p. 6-4).

13.3.3 Using Decision Tables to Present Decision Steps

Another technique for presenting decision steps that can be used in both algorithmic and big-picture flowcharts is the decision table. A decision table consists of two regions, one that specifies the conditions, a set of which must be satisfied simultaneously; and one that specifies actions, which are taken when the corresponding conditions are satisfied. Figure 13.10 shows an example of a one-dimensional decision table and Figure 13.11 shows an example of a two-dimensional decision table. There are cases when a decision table within a flowchart may be preferable to a series of flowchart steps. For simple problems, decision tables can be used more quickly than flowcharts. However, tables presented in a two-dimensional matrix can be difficult to understand and their use can lead to errors.

So that decision tables are readily understood, use these techniques.

- Place decision tables that include operator actions in the flowpath (Section 4.2, p. 4-2; Section 5.2.3, p. 5-2; Section 6.2, p. 6-2).

- Format decision tables that include supplemental information as notes (Section 6.5.1, p. 6-37). Do not include actions in these notes (NUREG-0899, Section 5.7.10, p. 24).

- Use only one- or two-dimensional decision tables. If one axis contains multiple criteria, indicate this graphically; do not use combinations of Ys and Ns. Do not use more than two criteria on an axis (Section 6.4.2.3, p. 6-26).

13.3.4 Using Logic Statements to Present Decision Steps

Logic statements are used in text EOPs to describe a set of conditions and a related sequence of actions. Because of their frequency of occurrence in EOPs and their complexity, it is important that they be used correctly. The combination of logic statements with action symbols is potentially subject to the problems of confusion inherent in the use of logic statements in text procedures, and may in fact be even more confusing, since action symbols are being used inconsistently to present both action instructions and decisions. Therefore, it is particularly important that the guidance provided in Appendix B of NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, be followed when constructing logic statements for big-picture flowcharts. To ensure that decision steps composed of logic statements are correctly formatted, use the following techniques derived from NUREG-0899.

- Use only the logic terms IF, WHEN, THEN, AND, OR, and IF...NOT.

- Use IF to introduce possible conditions.

- Use WHEN to describe conditions that will occur.

- Use THEN to introduce an action dependent on the condition introduced by IF or WHEN. Never use THEN without IF or WHEN.

- Use AND to join a set of conditions that must all be met. When joining three or more conditions, use a list format.

Adequate Subcooling Margin

RCS PRESS	MARGIN
> 1500 psig	Maintain ≥ 20 °F
≤ 1500 psig	Maintain ≥ 50 °F

FIGURE 13.10. One-Dimensional Decision Table

RCS Temp Indication

	RCP ON	RCP OFF	
		Natural Circulation	No Natural Circulation
HPI ON	Tc	Incore T/C	Incore T/C
HPI OFF	Tc	Tc	N/A

Incore T/C is the average of the 5 highest incores.

FIGURE 13.11. Two-Dimensional Decision Table

- Use OR to join a set of conditions when one or more of those conditions must be met (that is, the inclusive case). When joining three or more conditions, use a list format.

- To indicate the exclusive OR, use "A OR B but not both."

- Do not use NOT alone. NOT should be used only with IF; for example, "IF the reactor has NOT tripped, THEN...."

- Limit the use of AND and OR together. If it is necessary to use AND and OR together, use a decision table rather than combining AND and OR in the same logic statement.

13.4 CAUTIONS AND NOTES

Presenting cautions and notes in flowchart EOPs is problematic. Cautions address conditions, practices, or procedures that must be observed to avoid personal injury, loss of life, a long-term health hazard, or damage to equipment (NUREG-0899, Section 5.7.9, p. 24). Notes provide supplemental information that may be helpful to operators (NUREG-0899, Section 5.7.10, p. 24). If a procedure contains many long cautions and notes, the cautions and notes may dominate the image of the flowchart, obscuring the structure created by the decision and action steps. Further, placing cautions and notes outside of the flowpaths may, in some cases, save a significant amount of space on the flowchart sheet.

However, in most cases the disadvantages of placing cautions and notes outside of flowpaths outweighs the advantages of such placement. It is especially important that a caution be placed directly in the flowpath immediately prior to the step to which it applies. Further, cautions should be accented through the use of a dissociative variable (size or value variation) to ensure that they are seen. It is conceivable that the advantages of placing notes outside of the flowpaths may outweigh the disadvantages of such placement. This may be the case if an EOP contains many references to long note statements and the potential problems of placing the notes outside of the flowpaths can be minimized.

Use these techniques to present cautions and notes.

- Place cautions directly in the flowpath, unless they are large and will visually dominate the flowchart (NUREG-0899, Section 5.5.3, p. 19). If a caution is much longer than the majority of action steps on the page, locate it to the side of the flowchart and reference it with a distinctive symbol such as a large letter or number and with a descriptive title (Section 6.5.1, p. 6-37).

- Do not place notes directly in the flowpath, because the structure of the flowpath should be determined by the decisions and actions to be made rather than by the supplemental information contained in the notes (NUREG-0899, Section 5.5.3, p. 19; Section 6.5.1, p. 6-37).

- In vertical flowpaths, place notes to the left of the flowpath and connect them to the flowpath with dashed lines. Placing notes to the left of flowpaths will make efficient use of space and help balance flowcharts, as the longer and more complex branches in the flowchart will tend to move to the right (Section 6.2, p. 5.5.3; Section 6.5.1, p. 6-37).

- In a vertical flowpath, connect the note to the flowline immediately prior to the first step to which the note applies. At least the first three lines of the note's text should be positioned above the applicable step, as shown in Figure 13.12 (NUREG-0899, Section 5.5.3, p. 19).

- Position notes in horizontal flowpaths <u>above</u> the steps to which they apply. Connect them to the flowline by a dashed line that intersects the main flowline at a point immediately prior to (i.e., to the left of) the step symbol to which the note applies (see Figure 13.13) (Section 5.4, p. 5-45).

- Do not place notes close to adjacent flowpaths to which the notes do not apply. If necessary, add additional white space between adjacent flowpaths so that each note is positioned closer to the flowpath to which it applies than it is to an adjacent flowpath (Section 4.2, p. 4-2; Section 5.2.3, p. 5-2).

- Avoid placing other items near cautions, such as symbols in adjacent flowpaths, flowlines, or notes, so that the dark border of the caution can contrast against a relatively large area of white space (Section 4.1, p. 4-1).

- Emphasize cautions with a dissociative variable such as a rectangle with a heavy border (see Figure 13.14) (NUREG-0899, Section 5.5.3, p. 19; Section 6.5.1, p. 6-37).

- Do not include operator actions in notes and cautions (NUREG-0899, Section 5.7.9, p. 24; NUREG-0899, Section 5.7.10, p.24).

- Place notes in a rectangle consisting of dashed lines (Section 6.5.1, p. 6-37).

- Use an identical dashed line to connect the note to the flowpath to promote a sense of unity between the symbol and the flowpath (Section 4.2, p. 4-2; Section 4.5, p. 4-4).

- Connect the dashes at the corners of the rectangle that encloses the note text so that the right angles are clear to help define the shape of the symbol (Section 5.3.2.5, p. 5-20).

- Do not separate a caution from the step(s) to which it applies with a page or column break (NUREG-0899, Section 5.5.3, p. 19).

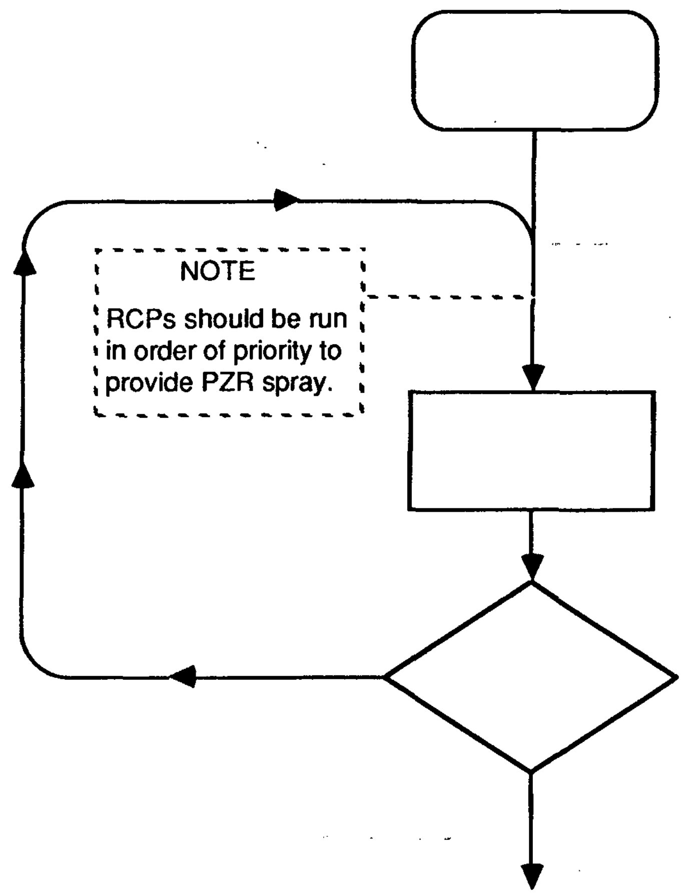


FIGURE 13.12. Vertical Flowpath with a Note

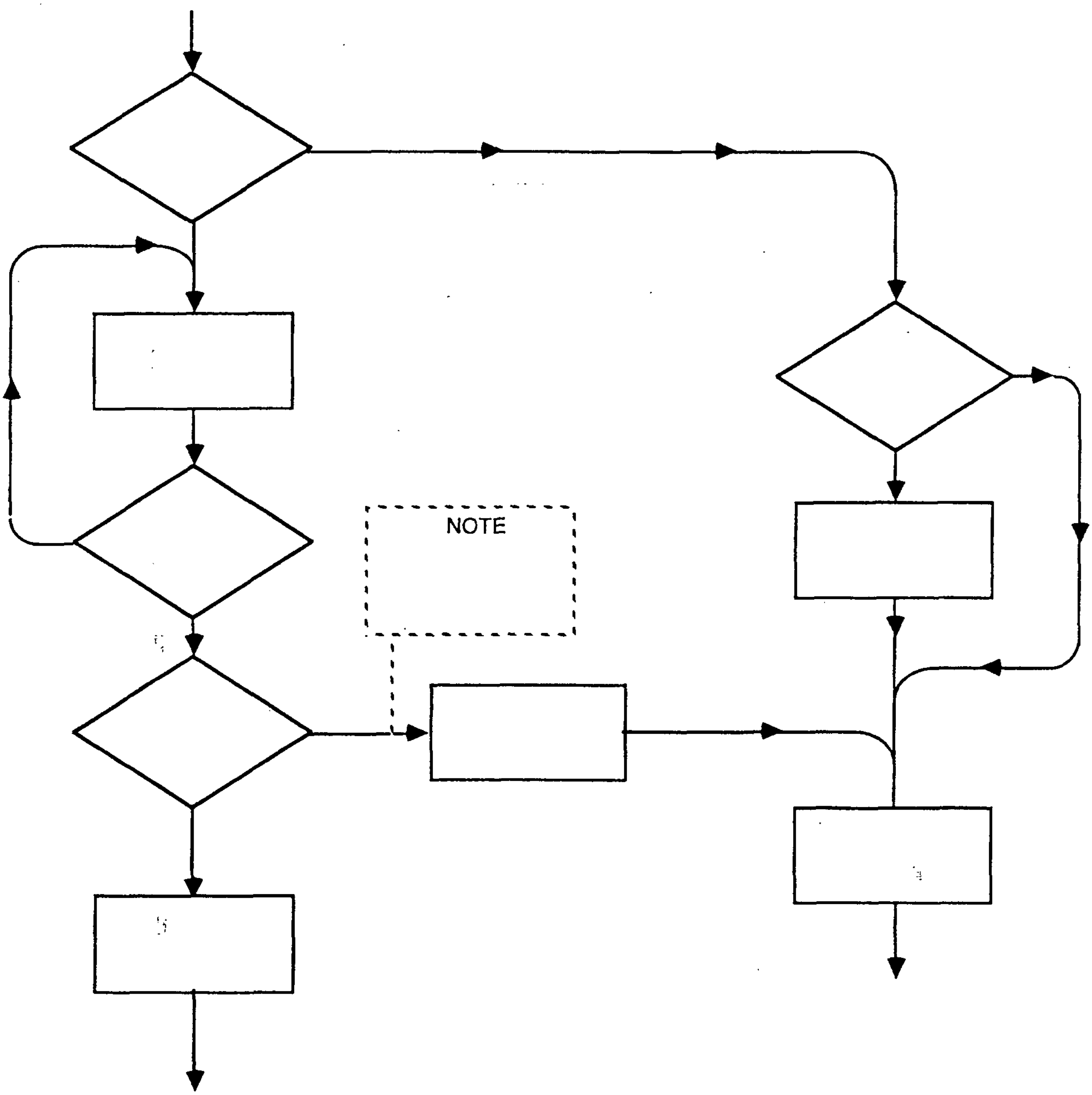


FIGURE 13.13. Note in a Horizontal Flowpath

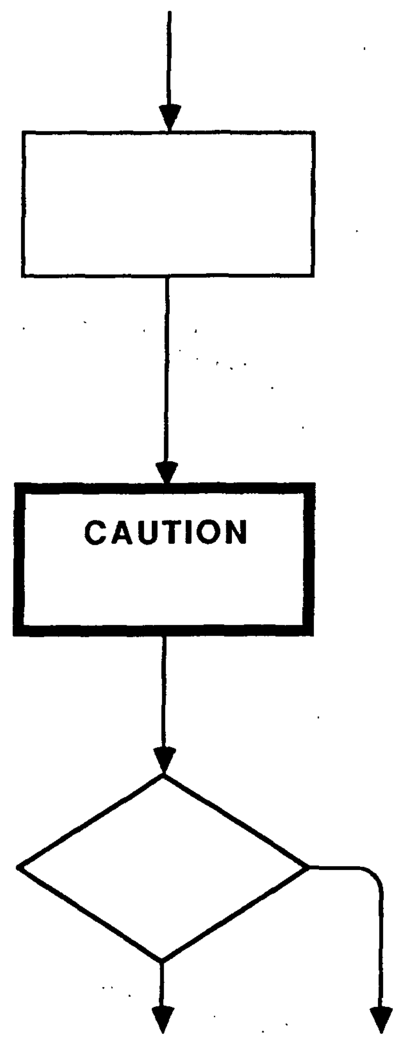


FIGURE 13.14. Caution Symbol

13.5 FIGURES AND TABLES

Figures and tables are useful methods of condensing information and presenting it in EOPs (NUREG-0899, Section 5.5.8, p. 20). In contrast to the preferred location of figures and tables in text EOPs, figures and tables in flowcharts, with the exception of decision tables, should not be placed near the steps to which they apply for several reasons. First, figures and tables may be larger than actions steps in a flowpath and so would inappropriately draw attention away from more important information. Second, figures and tables may obscure the flow of activity shown by the structure of the flowpath and so reduce the understandability of the flowchart. Third, the rectangular shapes that are necessary to enclose figures and tables and that indicate that the information in the figure or table is a unit could be confused with an action step or a decision table. Therefore, figures and tables should be placed outside of flowpaths in a consistent location on the flowchart or presented as job performance aids, and referenced in the relevant action or decision steps. Many of the principles of graphic design addressed in this report are applicable to the development of figures and tables for flowchart procedures.

Use these techniques when presenting information in figures and tables.

- Place figures and tables other than decision tables outside of the flowpath, in a consistent location on each flowchart sheet (Section 4.5, p. 4-4).

- Cite figures and tables with a parenthetical note inside of the relevant step. Reference figures and tables by name, number, and grid location (NUREG-0899, Section 5.5.8, p. 20).

- Include in figures and tables only the relevant information needed to clarify the text of the flowchart, or to accomplish a purpose referenced in the text of the flowchart (NUREG-0899, Section 5.5.8, p. 20).

- Prepare figures and tables according to standard graphics practices and the graphics principles discussed in Volume 1 of this report (NUREG-0899, Section 5.5.8, p. 20; Section 4.0, p. 4.1).

- If possible, number figures and tables in the order in which operators will first be referenced to them when executing the flowchart (NUREG-0899, Section 5.5.8, p. 20).

- Ensure that figures and tables are legible (NUREG-0899, Section 5.5.8, p. 20).

- Do not used reduced figures or tables (NUREG-0899, Section 53, p. 15).

- Ensure that the units of measure used in figures and tables are consistent with other procedures and control panel markings (NUREG-0899, section 3.3.5.1d, p. 10; Section 8.1.2, p. 8-3).

13.6 IDENTIFYING INFORMATION

As is the case with text EOPs, flowchart sheets should contain complete page identification information to help ensure that operators always use the correct flowchart. So that this information can be easily found on the flowchart, it should be grouped together in a box and placed in a consistent position on each flowchart.

Provide identification information as follows.

- Provide information that clearly identifies the flowchart on each page, so that operators are always certain that they are using the correct flowchart (NUREG-0899, Section 5.5.1, p. 18).

- Place a box containing procedure identification information in the lower-right corner of each flowchart (Section 5.3.1, p. 5-13).

- Include in this box (1) the procedure title; (2) the procedure number; (3) the revision number; (4) the unit designation; (5) the facility designation, if applicable; (6) review and approval signatures, and (7) the date of the most recent revision (see Figure 13.15) (NUREG-0899, Section 5.5.1, p. 18).

13.7 IDENTIFYING EQUIPMENT

To ensure that operators correctly find the equipment referenced in the flowcharts, the flowcharts should use the correct nomenclature when referring to equipment and location information should be provided for equipment that may be hard to find.

13.7.1 Equipment Nomenclature

References to equipment in flowcharts must balance the needs of identifying equipment in accurately understood terminology with the need to save space on the flowchart sheet.

When referring to specific equipment in flowcharts,

- Refer to commonly-used equipment in operator language (NUREG-0899, Section 5.6.1, p. 20).

- Present equipment labels exactly in flowcharts for instruments and controls that are infrequently used (NUREG-0899, Section 5.6.1, p. 20).

- Include this information in the action symbol rather than in a note (Section 4.6, p. 4-5).

Asbury Park Unit One	EOP-03	Rev 1	2/29/88
Primary Containment Control			
Reviewed:			
Approved:			

FIGURE 13.15. Identification Information

13.7.2 Location Information

The same constraints on presenting identifying information (i.e., understandable terminology, saving space) apply to presenting equipment location information. However, the operator ability to perform an action step correctly often depends on his or her ability to rapidly and accurately locate equipment outside of the control room.

- Because space is at a premium in flowcharts, do not present location information for commonly-used equipment with which operators are required to be familiar (Section 4.6, p. 4-5).

- Provide operators with information about the location of equipment, controls, or displays that are infrequently used, are in out-of-the-way places, or are otherwise difficult to find (NUREG-0899, Section 5.7.11, p. 24).

- If it is necessary to give location information, give the full name of the piece of equipment as it appears on the engraved panel marking and then give the location of the equipment. This information should always be given in a consistent format (Section 4.5, p. 4-4).

13.8 PLACEKEEPING

It is important to provide operators with placekeeping aids in flowcharts. However, placekeeping aids such as step numbers and check-off spaces, conventionally used in text procedures, can be problematic in flowcharts. Using either of these conventions would clutter the already visually complex image of the flowchart. Further, check-off spaces would be of only limited value in a flowchart with many loops. In a series of steps that may be repeated, the fact that a step has been checked-off does not necessarily mean that the step should not be performed again. A flexible placekeeping system, such as one that allows placekeeping marks to be made and erased as necessary, works well in flowcharts. A grid system can also be used on the border of flowcharts to assist operators in finding specific parts of the flowchart.

To facilitate placekeeping in flowchart EOPs, use these techniques.

- Consider laminating flowcharts so that operators can write on them with grease pencil (Section 6.6, p. 6-41).

- As an alternative, mount the flowchart on a metal surface so that a magnetized pawn or other marker can be used for placekeeping. Mark with pawns with a dissociative variable such as size, color, or dark value (Section 6.6, p. 6-41).

- Surround flowcharts with a border of at least one inch that constitutes the margin of the flowchart. Include the numbers and letters for the grid of the flowchart in the border, as shown in Figure 13.16 (Section 5.3.2.6, p. 5-24).

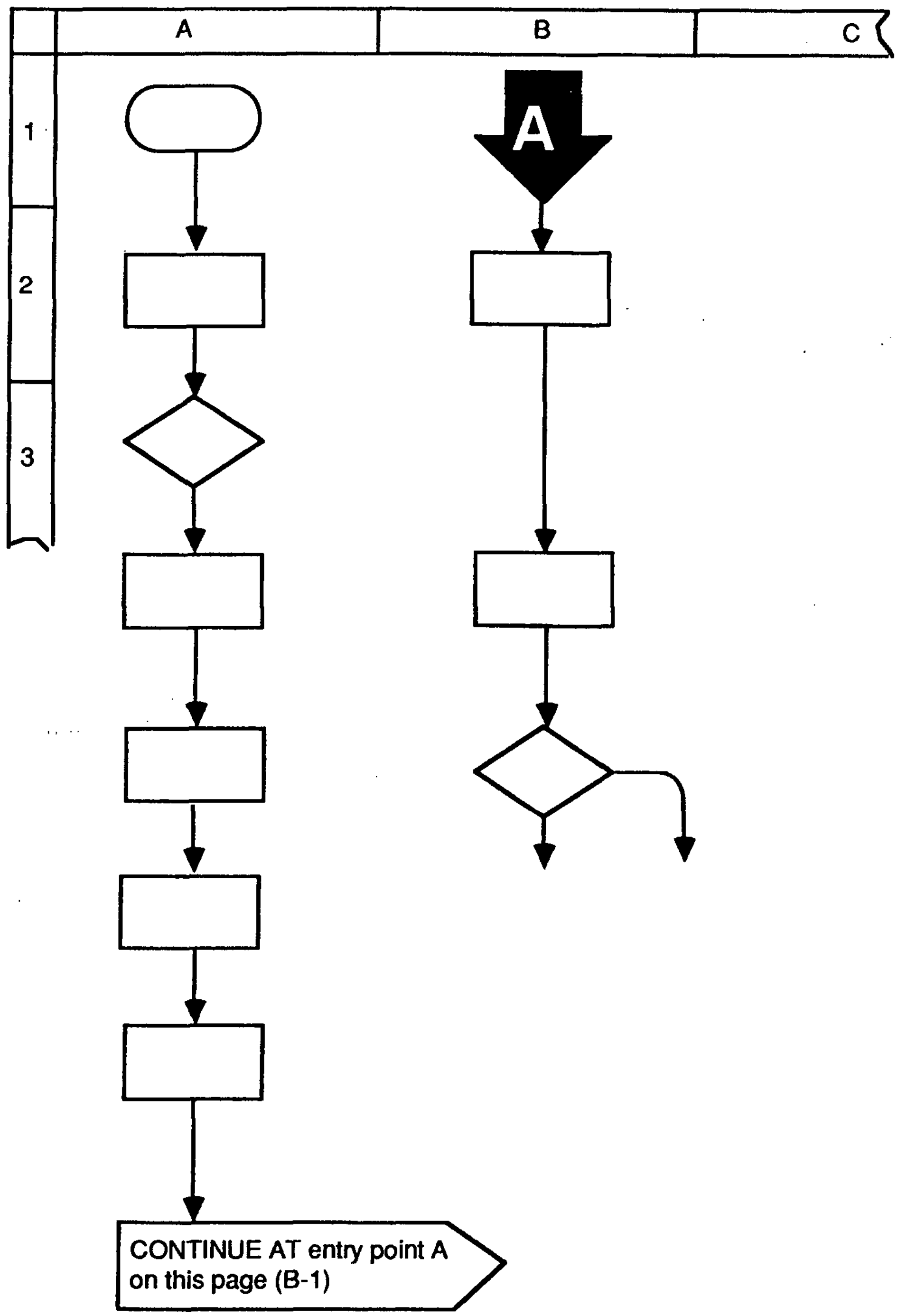


FIGURE 13.16. Grid in Flowchart Border to Facilitate Placekeeping

- Avoid the use of step numbers and check-off spaces in algorithmic flowcharts (Section 6.6, p. 6-41)

14.0 PRESENTING TEXT IN FLOWCHARTS

Text in flowcharts should be formatted to ensure legibility. The style of expression of flowchart text and the presentation of numerical information in flowcharts should promote clear understanding of the information being conveyed.

14.1 FORMATTING TEXT

Although the graphics of the flowchart can provide a variety of information to operators, the majority of information in a flowchart is communicated through text. Therefore, conventions for presenting text must ensure that it is readily and accurately understood. Text readability is fundamentally a function of the contrast between the letter and the surface on which the letter is printed. Given adequate contrast, readability is affected by four additional factors: (1) the size of the type, (2) the case of the type, (3) the type font that is used, and (4) how the text is justified.

14.1.1 Contrast

- To ensure text is presented with the sharpest possible contrast, use black type on a white background (Section 4.1, p. 4-1; Section 5.3.7.2, p. 5-40).

- Ensure that all printing and duplication of flowcharts is of high quality. Poor printing or poor duplication (smudges, faded or blurred letters, etc.) will reduce legibility (Section 8.4, p. 8-6; NUREG-0899, Section 6.2.2, p. 27).

- If a dot matrix printer is used to produce flowchart text, pay particular attention to the quality of the type. Use only dot matrix printers that produce near letter-quality output and ensure that the type quality remains high; change the ribbon frequently and clean the printer head frequently (Section 8.4, p. 8-6).

14.1.2 Type Size

The type in a flowchart must be large enough so that it can be read from an appropriate distance. For example, if a flowchart is mounted on a wall above a horizontal control panel, the type should be readable by an operator without the operator being required to lean over the horizontal panel. Appropriate type size is determined by considering the visual angle created by the viewer's eye and the top and bottom of a letter. The recommended techniques below use a formula to calculate text size. The basis of this formula is explained in Appendix D of this volume.

- The formula presented in Appendix D should be used to calculate the size of the smallest letter used in the flowchart, not the actual type size, which is likely to be different from the height of the smallest letter in a font of that type size (Section 7.1, p. 7-1).

- If the operator must alternately read the flowchart and look at distant panels, a type size larger than the minimum may be necessary (NUREG-0899, Section 5.3, p. 15; Section 7.1, p. 7-1).

- Use a type size that conforms to the rules:

$$L_o = 0.0044D$$
$$L_d = 0.0061D$$

  where D is the distance from which the flowchart will be read, L_o is the minimum height of the smallest letter (not the type size in points) in optimal lighting, and L_d is the height in degraded lighting (Section 7.1, p. 7-1).

14.1.3 Line Spacing

In addition to type size, the spacing between text lines influences the readability of text. Because of space limitations in flowcharts, line spacing should not be excessive, but lines of text should not be too close to each other, or to the lines forming the tops and bottoms of flowchart symbols.

To ensure that the line spacing in flowcharts contributes to the readability of text:

- Single-space flowchart text (NUREG-0899, Section 5.5.2, p. 18).

- Provide a half-line space, in rectangular symbols, between the top of the symbol and the first line of text, and between the last line of text and the bottom of the symbol (Section 4.1, p. 4-1).

- Ensure that lines of text do not extend beyond the sides of symbols (Section 4.7, p. 4-6; Section 5.3.3, p. 5-26).

14.1.4 Type Face

Three major visual aspects of a type face are as follows: (1) whether the type face is serif or sans serif, (2) whether or not the type face is bold, and (3) whether or not the type face is italics. Because the size of the type in a flowchart is often near the lower end of the legibility scale, simpler type faces might be easier to read, because they include less visual noise. Thus, sans serif type is preferred in flowcharts; however, a serif typeface of sufficient size ought not to present legibility problems.

When selecting a type font for flowcharts,

- Use a readable type font. Sans serif type is preferred (Section 7.3.1, p. 7-6).

- Do not use italics (Section 7.3.2, p. 7-7).

- Do not use bold type, especially in smaller type faces (Sections 5.2.3, p. 5-2; Section 7.3.3, p. 7-7).

14.1.5 Capitalization

Text in a flowchart can be written in all capitals, or in mixed case, where words are capitalized according to standard English usage (that is, proper nouns and the first letter of each sentence are capitalized). There are advantages to each approach: capital letters are larger, and can be read at a greater distance while lower-case letters are more distinct, because there is a greater variation in their size and shape. When not appearing in a block of text, words printed in all capitals are easier to read, presumably because capital letters are larger than lower case letters. However, blocks of text are more easily read when presented in mixed case.

To promote the effective use of capitalization in flowcharts,

- Use mixed case for blocks of text in big-picture flowcharts (Section 7.2, p. 7-3).

- Full capitalization may be used for text in algorithmic flowcharts (Section 7.2, p. 7-3).

- Use full capitalization for emphasis in those instances described in Section 15.1.3.

14.1.6 Justification

There are two ways in which text in a rectangular box, such as an action symbol, can be formatted to create rectangular blocks of text. Text can be set ragged-right (i.e., with lines of different lengths), or flush right (i.e., with lines of equal lengths). Text that is set flush right is called "justified" text. Justified text is created by adding extra spaces between words on short lines so that all lines of text equal the length of the longest line. Justified text is difficult tc read when line lengths are short, as in the lines of text within flowchart symbols.

When justifying text in flowchart symbols,

- Set rectangular blocks of text with a ragged right margin (unjustified) (Section 7.4, p. 7-7).

- Set text in diamond-shaped symbols so that the block of text is diamond-shaped (Section 4.7, p. 4-6).

14.2 STYLE OF EXPRESSION

The text in flowcharts should be easily understood and unambiguous (NUREG-0899, Section 5.6, p. 20). The words used in flowcharts should be the simplest, most familiar and most specific words that accurately convey the intended meaning. Operators should be familiar with all terminology--words, acronyms, abbreviations, and symbols--used in flowcharts. Sentence structure and punctuation should be consistent with standard American English usage.

It is important that text be kept as brief as possible in flowcharts, because of the space limitations inherent in flowcharts. However, the clarity of expression should not be sacrificed by using sentence fragments, faulty punctuation, or abbreviations, acronyms, and symbols that operators may not understand. Some space can be saved by omitting the final punctuation mark in text within a flowchart symbol, as the symbol shape indicates whether the text is a statement or a question.

14.2.1 Word Choice

- Use short words and words that are common in ordinary operator conversation (NUREG-0899, Section 5.6.1, p. 20).

- Use nomenclature and idioms that are familiar to operators and are standard at a particular plant and in the nuclear power industry (NUREG-0899, Section 5.6.1, p. 20).

- Use concrete and specific words that describe precisely what the operator is to do or observe (NUREG-0899, Section 5.6.1, p. 20).

- Use words and meanings consistently throughout procedures (NUREG-0899, Section 5.6.1, p. 20).

- Do not use adverbs that are difficult to define in a precise manner, such as "frequently" and "slowly (NUREG-0899, Section 5.6.1, p. 20).

14.2.2 Sentence Structure and Punctuation

- Use a concise, but not telegraphic, writing style. Statements and questions should be short but should include forms of "to be" and "to have" where appropriate (NUREG-0899, Section 5.6.3, p. 21).

- When punctuation is necessary, punctuate text in flowcharts according to standard English usage. Any deviations from standard English usage should be covered in the writer's guide and discussed during training (Section 8.2, p. 8-5; Section 8.3, p. 8-6).

- In algorithmic flowcharts, omit punctuation marks at the ends of sentences (i.e., the periods and question marks) in decision steps and action steps if the step contains only one sentence and if that sentence requires no internal punctuation (Section 4.6, p. 4-5).

- Do not use long sentences in flowcharts. If a sentence requires much punctuation, it is probably too long and should be broken into separate sentences (NUREG-0899, Section 5.6.3, p. 21).

14.2.3 Acronyms, Abbreviations, and Symbols

- Ensure that the acronyms, abbreviations, and symbols used in flowcharts are familiar to operators so that there is no need to consult a glossary (NUREG-0899, Section 5.6.2, p. 20; Section 8.2, p. 8-5).

- Ensure that acronyms, abbreviations, and symbols used in the flowcharts are consistent with control panel markings (NUREG-0899, Section 5.6.2, p. 20; Section 8.1.2, p. 8-3).

- Do not use acronyms, abbreviations, or symbols that have multiple meanings (Section 4.5, p. 4-4).

- Do not use more than one acronym, abbreviation, or symbol for a single term, unless the acronyms, abbreviations, or symbols correspond to different control panel markings (Section 4.6, p. 4-5).

14.3 NUMBERS

- Use Arabic numerals in flowcharts. Do not spell numbers out (NUREG-0899, Section 5.6.7, p. 21; Section 5.2.2, p. 5-2).

- Express limits quantitatively (NUREG-0899, Section 5.6.8, p. 21).

- Express limits as a range. For example, express limits as "80 to 100 inches," not "90 ± 10 inches" (NUREG-0899, Section 5.6.8, p. 21).

- Provide units of measure for all numbers. Ensure that these units of measure correspond to control panel and instrument markings (NUREG-0899, Section 5.6.6, p. 21; Section 8.1.2, p. 8-3).

- If possible, do not require operators to perform a calculation while executing a flowchart. Provide a graph, decision table, or a series of decision steps instead of requiring a calculation (NUREG-0899, Section 5.6.9, p. 20; Section 6.4.6, p. 6-35).

15.0 EMPHASIS TECHNIQUES

Emphasis techniques can serve two purposes in flowcharts. Emphasis techniques can be used to draw operators' attention to important information in the EOPs and to the relationships of flowchart elements. Emphasis techniques for drawing attention to important information in procedures include such techniques as bolding, color-coding and underlining words. Emphasis techniques that draw attention to relationships of flowchart elements include the use of position variation and step numbering and grouping techniques.

15.1 EMPHASIZING INDIVIDUAL FLOWCHART ELEMENTS

The individual items that can be emphasized in flowcharts include flowlines, symbols, and blocks of text.

15.1.1 Dissociative Variations

Dissociative effects are created by the prominent positioning of items, increasing the size of flowchart elements, or darkening the appearance of the flowchart elements. Because emphasis is a matter of contrast, the overuse of emphasis detracts from its effectiveness.

To use dissociative variations effectively for emphasis, use these techniques.

- Vary the number of arrows on parallel flowlines as shown in Figure 12.12. The increased use of arrows on the outer flowlines makes the flowlines appear dark, thus making it easier for operators to distinguish the separate flowlines (Section 5.2.3, p. 5-2; Section 6.3.3.4, p. 6-21).

- In big-picture flowcharts, surround cautions in borders that are heavier than flowpath lines but lighter than the brackets used in override steps, as shown in Figure 15.1 (Section 4.1, p. 4-1; Section 5.3.3, p. 5-26).

- In override steps in big-picture flowcharts, draw the brackets surrounding the affected steps and the border surrounding the text of the override step to be much darker than flowpath lines (see Figure 15.1) (Section 4.1, p. 4-1; Section 5.3.2.5, p. 5-20).

15.1.2 Color Coding

Used properly, color can be a powerful emphasis technique. It may be especially useful in complex flowcharts, because additional information can be communicated through color without adding extra visual noise to the flowchart. However, poorly used color can seriously impair communication.

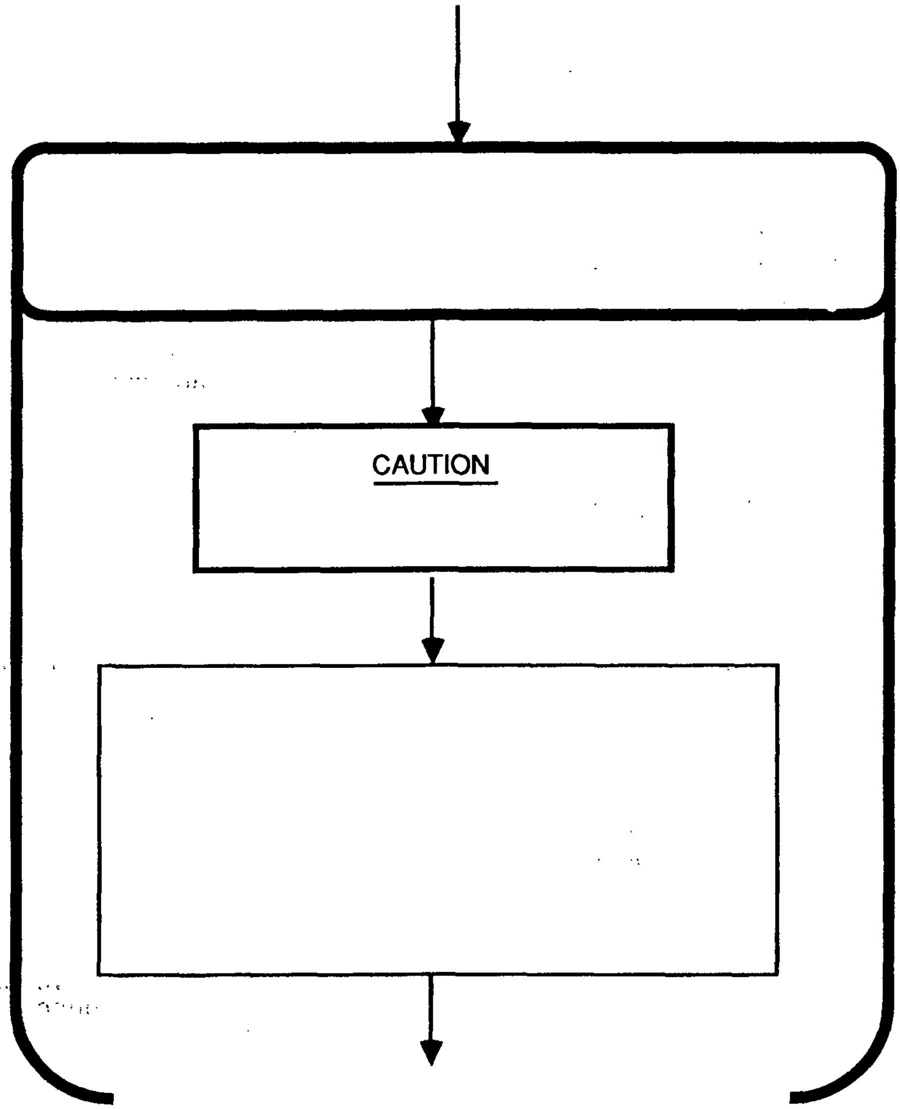


FIGURE 15.1. Comparative Values of Caution Border and Override Step

- Use color sparingly, as this will promote the effectiveness of color emphasis and prevent faulty perception of colors (Section 5.3.7.3, p. 5-41; Section 5.3.7.4, p. 5-42).

- Use colors consistently (Section 4.5, p. 4-4).

- To ensure that colors are distinct and highly visible, use only highly saturated colors that are of markedly different hues (Section 5.3.7.2, p. 5-40).

- Do not use blues and cyans with reds, extreme color pairs such as yellow with purple, or red with blue, as such combinations promote eyestrain (Section 5.3.7.4, p. 5-42).

- Use only colors that contrast strongly in value with the background (Section 5.3.6, p. 5-36). If the background is the white page of the flowchart, use dark colors. However, vary the value of the colors some to ensure that the different colors are distinct (Section 5.3.7.2, p. 5-40).

- If possible, use hues that are most distinct for the relative values of the colors. Use colors within the spectral sequence blue-purple-red with dark values. Use colors within the spectral sequence orange-yellow-green for light values (Section 5.3.7.2, p. 5-40).

- Do not use color as the only means of conveying a piece of information. Only use color to reinforce information already expressed through text or through another graphic variable. Because hues, values, and levels of saturation can appear to shift as a result of various factors (e.g., the color's environment, prolonged viewing) color is not a reliable means of coding information (Section 5.3.7.3, p. 5-41; Section 5.3.7.4, p. 5-42).

- Use color for marking large areas, rather than for details. For example, use colored panels around a portion of a flowchart to graphically group related steps rather than drawing the borders of those steps with a color. Color is more reliably perceived in large areas (Section 5.3.7.3, p. 5-41).

- If two colored areas touch each other, then ensure that the colors differ in value as well as in hue so that the boundary is visible (Section 5.3.7.3, p. 5-41).

- To ensure that colors are distinct, do not use similar hues of reds and purples (Section 5.3.7.2, p. 5-40).

- If possible, to ensure that colors are distinct, use complimentary colors (Section 5.3.7.2, p. 5-40).

- Do not use red or green near the borders of flowcharts. If possible, only use blue or yellow near the borders of flowcharts (Section 5.3.7.3, p. 5-41).

- If a sequence of colors is used to show an ordered relationship, such as the relative priorities of flowpaths, use one of the following sequences:

  - A sequence that operators are thoroughly trained to recognize and understand (Section 5.3.7.3, p. 5-41; Section 8.2, p. 8-5).

  - A spectral sequence of cool colors (blue-green-yellow) (Section 5.3.7.3, p. 5-41).

  - A spectral sequence of warm colors (yellow-orange-red) (Section 5.3.7.3, p. 5-41).

15.1.3 Text Techniques

Capitalization and underlining could be used to emphasize text in flowcharts. To ensure that the emphasis is effective, however, these techniques should be used only for a limited number of specific applications.

To emphasize text effectively, use these techniques.

- Fully capitalize and underline logic terms such as <u>IF</u>, <u>THEN</u>, and <u>OR</u> (NUREG-0899, Appendix B, p. 39).

- Fully capitalize referencing and branching terms such as CONCURRENTLY PERFORM and GO TO (Section 7.2, p. 7-3).

- Fully capitalize the words CAUTION and NOTE when these terms are used as headings for cautions and notes (Section 7.2, p. 7-3).

- Avoid using bold print and italics for text in flowchart EOPs (Section 7.3.3, p. 7-7).

- Minimize the use of underlining to emphasize text in flowchart EOPs, as underlining may distort the perception of symbol shapes (NUREG-0899, Section 5.5.2, p. 18; Section 4.7, p. 4-6).

15.2 EMPHASIZING PROCEDURE ORGANIZATION

Step numbering and grouping techniques can be used to emphasize the organization of text EOPs (NUREG-0899, Section 5.5.5, p. 19), but are problematic in flowchart EOPs. All of the problems associated with step numbering and grouping techniques in flowchart EOPs are typically more pronounced in algorithmic flowcharts, which tend to be visually complex and highly branched, than in big-picture flowcharts, which tend to be visually simpler than algorithmic flowcharts and which are a hybrid of text and flowcharts. With regard to step numbering and grouping, use these techniques.

- Use position variation to separate logically separate items and to group related items close together to emphasize logical relationships in the procedure (Section 5.3.1, p. 5-13). However, do not sacrifice legibility when grouping items (Section 3.2.2, p. 3-22; Section 4.8, p. 4-11).

- Do not use a step/substep hierarchy in the flowpaths of algorithmic flowcharts. When using flowcharts, operators perform each action or decision as it is encountered, and then continue. Thus, if steps are presented as high-level steps with substeps, the steps appear as though they should be performed twice, once as the high-level step is enountered and again when the substeps are encountered (Section 3.1.3.2, p. 3-19; Section 3.1.3.3, p. 3-21).

- Do not number steps in algorithmic flowcharts and avoid numbering steps in big-picture flowcharts. Because of the branching structure of the flowchart, operators do not move through the flowchart in a step-by-step manner. Thus, knowing the number of the current step does not necessarily provide an operator with information about where he has been or where he is going in the flowchart (Section 6.6, p. 6-41).

- Because graphic grouping techniques, such as brackets and boxes, can lead to clutter, do not group related steps in the flowpaths of algorithmic flowcharts with graphic devices such as boxes or brackets (Section 4.6, p. 4-5).

- If higher-level steps with substeps are used in big-picture flowcharts, present the steps and substeps within the same symbol. Because big-picture flowcharts are a hybrid of text procedures and graphics, they can accommodate higher-level steps and substeps more readily than can algorithmic flowcharts. Indent and bullet substeps, as shown in Figure 15.2 (Section 3.2.2, p. 3-22).

IF torus water level is below 183 in.
AND drywell pressure and temperature are below the DSIL,
THEN:

- Shut down the reactor circulation pumps
- Shut down the drywell cooling fans
- Initiate drywell sprays

FIGURE 15.2. High-Level Steps and Substeps in a Big-Picture Flowchart

16.0 IMPLEMENTATION AND MAINTENANCE OF FLOWCHART EOPs

Once the flowchart EOPs have been prepared, a number of additional issues should be addressed before they are implemented. These issues include the incorporation of placekeeping methods, validating and verifying the flowchart EOPs, training operators to use the flowchart EOPs, and producing and revising them.

16.1 VALIDATING AND VERIFYING THE FLOWCHART EOPs

Validation and verification of EOPs are the processes used to ensure that the EOPs are technically accurate and are usable by operators. NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures (USNRC, 1982), and Section 8.1 in Volume 1 of this report discuss the objectives of EOP verification and validation programs that should be met for flowchart EOPs and methods for meeting the objectives. Because of the unique format of flowchart EOPs, there are some additional concerns that should be addressed during validation and verification that are not relevant to text EOPs. These concerns include the reduced level of detail in flowchart EOPs, physical use of large flowcharts, and the execution of concurrent procedures.

To ensure that flowchart EOPs are technically accurate and usable by operators, consider the following techniques.

- Include newly certified operators, human factors experts, technical experts, and flowchart designers in the validation and verification of flowchart EOPs (Section 8.1, p. 8-1)

- Provide sufficient space in the control room for using the flowcharts. If only a single flowchart is to be used at any given time, then a table or easel should be provided that is large enough to accommodate the largest flowchart in the set plus any extra flowchart paraphernalia (e.g., grease pencils, spray cleaner, and rags used to mark and clean the flowchart to facilitate placekeeping). If several flowcharts are to be used simultaneously, the table or easel must be large enough to allow several flowcharts to be laid down at the same time while leaving space for additional flowcharts to be stacked on the table (Section 8.1.3.2, p. 8-4).

- Do not require operators to carry and use large flowcharts at the control panels or out in the plant, as the flowcharts will be cumbersome and may obscure important displays (Section 8.1.3.2, p. 8-4)

- Ensure that operators are able to follow multiple EOPs concurrently in big-picture flowcharts by including scenarios that encourage "tunnel vision" in the simulator validation exercises (Section 8.1.3.3, p. 8-5)

- Ensure that the text in the flowchart EOPs is legible by operators under conditions of expected use and in degraded lighting (Section 7.0, p. 7-1)

16.2 TRAINING OPERATORS TO USE FLOWCHART EOPs

The unique concerns raised by flowchart EOPs (i.e., level of detail, physical use, execution of concurrent procedures) should also be addressed when training operators to use them. Including the flowchart designer in operator training sessions can ensure that revisions to the flowcharts will be made to address any problems that arise in these or other areas (Section 8.2, p. 8-5)

16.3 PRODUCTION AND REVISION

Flowchart EOPs are generally more complicated to produce and revise than text procedures. Text EOPs should be prepared by a team comprised of persons with expertise in plant operations, in engineering, in operator training, and in human factors or technical writing (NUREG-0899, Section 3.3.4, p. 9). Flowcharts also require expertise in graphics to prepare (Section 8.4, p. 8-6). Thus, graphic artists or consultants who have experience with graphics should be available. Computer drafting experience may also be required.

- Ensure that the quality of all flowchart reproductions is equal to the quality of the original flowchart (NUREG-0899, Section 6.2.2, p. 27; Section 5.3.8, p. 5-43; Section 8.4, p. 8-6)

- Ensure that the flowcharts are revised in a timely manner to reflect changes in the plant design, technical specifications, technical guidelines, writers' guide, other plant procedures, or the control room (NUREG-0899, Section 6.2.4, p. 27; Section 8.4, p. 8-6).

- Ensure that the flowcharts are revised in a timely manner when operating and training experience, simulator exercises, control room walk-throughs, or other information indicate that incorrect or incomplete information exists in the flowcharts (NUREG-0899, Section 6.2.3, p. 27; Section 8.3, p. 8-6)

- Ensure that flowcharts can be revised as needed by developing in-house revision capabilities or contracting for them (Section 8.3, p. 8-6)

- Develop a method for incorporating temporary changes into the flowcharts that does not clutter the flowchart page or distort flowchart elements (Section 8.4, p. 8-6)

17.0 DEVIATIONS FROM THESE TECHNIQUES

Flowchart design is a complex process. During this process it may be necessary to deviate from one desirable design attribute in order to enhance another. Further, many of the specific techniques presented here can be viewed as hypotheses derived from the literature or from experience that require confirmation through further research and application. Therefore, the specific techniques provided here are not intended to be followed so rigidly that innovative improvements in flowchart design cannot be pursued. Instead, these techniques are intended only to provide a basis for developing usable flowchart EOPs.

APPENDIX D

MEASUREMENT OF TYPE SIZE

MEASUREMENT OF TYPE SIZE

The process of selecting character size has been greatly simplified using the following formula, which is discussed in Section 5.5.1:

$$V = (57.3)(60)(L/D).$$

In this formula, L represents the height of the character in inches; D is the distance from the observer's eye to the object in inches; and V is the visual angle, expressed in minutes of arc (mins).

Two visual angles that are of importance for the use of this formula are 15 and 21 mins. According to Bailey (1982), good lighting conditions require a letter to subtend at least 15 mins or arc. In contrast, degraded or poor lighting would require a letter to subtend at least 21 mins of arc. Depending on the nature of the environment, the values of 15 or 21 may be plugged into the formula and used as constants. Therefore, if one were interested in selecting a type size suitable in optimal lighting conditions, one would let V=15.

Distance (D) must be calculated before the formula may be solved for type height (L). It should be mentioned at this juncture that since it is necessary to have the flowchart readable to a wide range of people, the distance should be calculated using subjects with varied heights or heights that will be representative of the population, and selecting type that can be read by the observer that will be farthest from the flowchart; that is, if the flowchart is to be read from a table, the flowchart should be readable by the tallest observer. Distance is determined by measuring the distance from the viewers' eyes to the actual object. It is important to use the dimensions of the actual flowchart to determine the most distant point on which the viewers will have to focus from their viewing position. Therefore, one should measure the distance from the viewers' eyes to the most distant part of the flowchart, as shown in Figure D.1. It is also important that measurements remain consistent, and therefore, a designated position should be selected for all viewers to stand. In addition, measurements should be taken with the subjects standing in similar positions (i.e., fully erect or leaning over). Distance is measured and plugged into the equation.

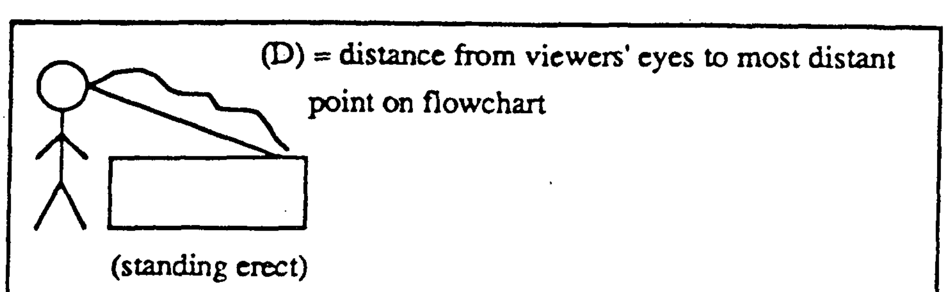


FIGURE D.1. Standing Operator Reading Flowchart

In this example, distances were measured for men and women using heights representing the 5th and 95th percentiles, as based on anthropometric statistics compiled in 1972. The table height was 29", a standard desk size, and the flowchart used was 24"x36". The flowchart was designed to be read horizontally, and the distance, therefore, was measured from the viewers' eyes approximately 36" to the far edge of the flowchart. The 5th and 95th percentile heights in industrial working men were 66.1" and 74.4", respectively. In industrial working women, the 5th and 95th percentile heights were 59.7" and 67.5", respectively. Table D.1 represents the values derived using the formula during optimal and degraded lighting conditions while the viewer was standing in an erect position.

TABLE D.1. Letter Size for Standing Observers
Flowchart: 36" deep
Table: 29" high

	Men		Women	
	5th%	95th%	5th%	95th%
Optimal Lighting (V=15 mins)	.20	.23	.18	.21
Degraded Lighting (V=21 mins)	.28	.33	.26	.29

In Table D.1, the first row was calculated letting V=15, the visual angle that is suitable for optimal lighting. The second row was calculated letting V=21, the visual angle that is suitable for degraded lighting. As an example, letting V=15, and the distance (D)=54", for instance, one is able to multiply these amounts and divide by (57.3 x 60) to arrive at L in inches.

This table lists type sizes that would be readable to a wide range of people asked to review a 24"x36" flowchart while standing straight beside the table. In reality, however, the viewers will often lean over the table or position themselves to gain a better perspective. To illustrate the use of the formula a second time, distances were calculated having the viewer lean approximately 45 degrees over the flowchart, as shown in Figure D.2.

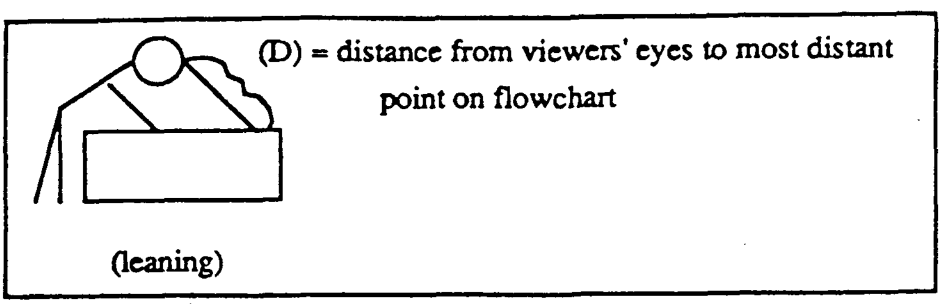


FIGURE D.2. Operator Leaning Over Flowchart

In a similar way, the distance was measured from the viewers' eyes to the object, or the furthest point on the flowchart. These new values were entered into the equation. Table D.2 illustrates the results.

TABLE D.2. Letter Size for Leaning Observers
Flowchart: 36" deep
Table: 29" high

	Men		Women	
	5th%	95th%	5th%	95th%
Optimal Lighting (V=15 mins)	.13	.17	.12	.14
Degraded Lighting (V=21 mins)	.19	.24	.16	.19

This formula has simplified the task of selecting type size in designing charts and panels. The formula, however, was designed to determine usable type heights for situations in which the reading material would be perpendicular to the viewers' eyes. In other words, "L" represents usable type size given the viewer is looking straight at the document. Once the material is no longer perpendicular to the viewers' eyes, as when placed on a table in the previous examples, it becomes necessary to adjust the angle. Therefore, using basic trigonometric calculations, one may determine the angle and adjust the size. The angle formed by the operators' line of sight and the table (lines ABC) will change the apparent size of L; see Figure D.3. The resulting size reduction of L can be estimated by multiplying sin ϕ by L. To avoid such a calculation, a plant may chose to err on the side of caution and choose a slightly larger type size.

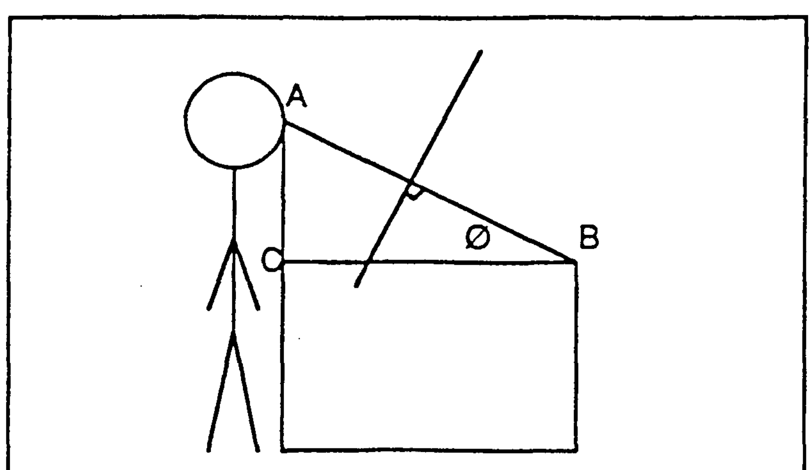


FIGURE D.3. Measuring the Angle of the Line of Sight

NUREG/CR-5228
PNL-6653
BHARC-700/88/017
Vol. 2
RX

DISTRIBUTION LIST

No. of Copies

OFFSITE

5 J. P. Bongarra, Jr.
U.S. Nuclear Regulatory Commission
NRR/DLPQ
Mail Stop 10D20,1WFN
Washington, D.C. 20555

J. W. Roe
U.S. Nuclear Regulatory Commission
NRR/DLPQ
Mail Stop 10H5,1WFN
Washington, D.C. 20555

W. H. Regan, Jr.
U.S. Nuclear Regulatory Commission
NRR/DLPQ
Mail Stop 10D20,1WFN
Washington, D.C. 20555

D. F. Ross
U.S. Nuclear Regulatory Commission
RES
Mail Stop NL-007
Washington, D.C. 20555

B. Sheron
U.S. Nuclear Regulatory Commission
RES/DSR
Mail Stop NLN-368
Washington, D.C. 20555

3 F. D. Coffman, Jr.
U.S. Nuclear Regulatory Commission
RES/HFB
Mail Stop NLN-316
Washington, D.C. 20555

No. of Copies

D. I. Serig
U.S. Nuclear Regulatory Commission
NMSS/IMNS/OB
Mail Stop 6-H3,1WFN
Washington, D.C. 20555

M. W. Hodges
U.S. Nuclear Regulatory Commission
NRR/SRXB
Mail Stop 8E-23,1WFN
Washington, D.C. 20555

ONSITE

26 Battelle Human Affairs Research Centers

V. E. Barnes (17)
C J. Moore
D. R. Wieringa
C. S. Isakson
B. K. Kono
R. Hooper
R. Shikiar
Library (2)
Records Center

24 Pacific Northwest Laboratory

R. L. Gruel (15)
L. J. Defferding
L. R. Dodd
W. C. Cliff
Publishing Coordination (1)
Technical Report Files (5)

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE.

1. REPORT NUMBER *(Assigned by TIDC, add Vol. No., if any)*

NUREG/CR-5227, Vol. 2
PNL-6653
BHARC-700/88/017

2. TITLE AND SUBTITLE

Techniques for Preparing Flowchart-Format Emergency Operating Procedures
User's Manual (Sections 10.0-17.0)

3. LEAVE BLANK

4. DATE REPORT COMPLETED

MONTH	YEAR
September	1988

5. AUTHOR(S)

V.E. Barnes, C.J. Moore, D.R. Wieringa, C.S. Isakson, B.K. Kono, R.L. Gruel

6. DATE REPORT ISSUED

MONTH	YEAR
January	1989

7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*

Battelle Human Affairs Research Centers
4000 N.E. 41st Street
Seattle, WA 98105
Pacific Northwest Laboratory
Richland, WA 99352

8. PROJECT/TASK/WORK UNIT NUMBER

P15166

9. FIN OR GRANT NUMBER

I2006

10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*

Division of Licensee Performance & Quality Evaluation
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

11a. TYPE OF REPORT

Technical Report

b. PERIOD COVERED *(Inclusive dates)*

July 1987 to September 1988

12. SUPPLEMENTARY NOTES

13. ABSTRACT *(200 words or less)*

This two-volume report describes the activities, findings, and recommendations of a project entitled "Techniques for Presenting Flowchart-Format Emergency Operating Procedures." The project team surveyed the literature pertaining to flowcharts, reviewed existing flowchart emergency operating procedures (EOPs), interviewed consultants who produced flowcharts, and interviewed reactor operator licensing examiners about the use of flowcharts in nuclear power plants.

Volume 1 of this report discusses the use of flowchart-format EOPs in nuclear power plants and presents issues to be addressed in the design and implementation of flowchart EOPs. Volume 2 presents techniques for preparing flowchart EOPs that were derived from the information discussed in Volume 1 and from NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures (USNRC, 1982).

14. DOCUMENT ANALYSIS – a. KEYWORDS/DESCRIPTORS

Emergency Operating Procedures - Nuclear Power Plants
Flowchart Procedures
Flowchart EOPs
EOPs
Decision Tables
Algorithms
Decision Aids

b. IDENTIFIERS/OPEN-ENDED TERMS

15. AVAILABILITY STATEMENT

Unlimited

16. SECURITY CLASSIFICATION

(This page) Unclassified

(This report) Unclassified

17. NUMBER OF PAGES

18. PRICE