

NEMA SB 2-2016

---

# Training Manual on Fire Alarm Systems



**NEMA Standards Publication SB 2-2016**

*Training Manual on Fire Alarm Systems*

Published by:

**National Electrical Manufacturers Association**

1300 North 17th Street, Suite 900

Rosslyn, Virginia 22209

[www.nema.org](http://www.nema.org)

© 2016 National Electrical Manufacturers Association. All rights, including translation into other languages, reserved under the Universal Copyright Convention, the Berne Convention for the Protection of Literary and Artistic Works, and the International and Pan American copyright conventions.

## NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

The National Electrical Manufacturers Association (NEMA) standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. While NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the document and it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its standards and guideline publications.

NEMA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA disclaims and makes no guaranty or warranty, express or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your particular purposes or needs. NEMA does not undertake to guarantee the performance of any individual manufacturer or seller's products or services by virtue of this standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health- or safety-related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.

## CONTENTS

Section 1 General .....	1
1.1 Scope .....	1
1.2 Referenced Standards .....	1
1.3 General Definitions .....	1
Section 2 Basic Fire Alarm Systems .....	16
2.1 General .....	16
2.2 Control Unit .....	16
2.3 Notification Methods .....	17
2.3.1 Non-coded System .....	17
2.3.2 Zoned Non-coded System .....	17
2.3.3 Coded System .....	17
2.3.4 Master Coded System .....	18
2.3.5 March-Time Coded System .....	18
2.3.6 Selective Coded System .....	18
2.3.7 Temporal Code 3 Pattern .....	18
2.3.8 Zoned Coded System .....	18
2.4 Emergency Communication Systems (ECS) .....	19
2.5 Control Unit Operation .....	19
2.6 Circuits and Pathways .....	21
2.7 Initiating Device Circuits (IDCs) .....	21
2.7.1 Two-Wire, Class B Circuit, using Initiating Devices and an End-Of-Line Device .....	21
2.7.2 Four-Wire, Class A Circuit, using Initiating Devices .....	22
2.8 Notification Appliance Circuits (NACs) .....	22
2.8.1 Two-Wire, Class B, Direct Current Notification Appliance Circuits .....	22
2.8.2 Two-Wire, Class B, Audio Notification Appliance Circuits .....	23
2.8.3 Four-Wire, Class A, Notification Appliance Circuits .....	23
2.9 Signaling Line Circuits (SLC) .....	24
2.10 Power Supplies .....	25
2.11 Supplementary Circuits and Devices .....	26
2.12 Types of Control Systems .....	26
2.12.1 Protected Premises (Local) Fire Alarm System (Chapter 23, NFPA 72) .....	26
2.12.2 Dedicated Function Fire Alarm Systems and Emergency Control Functions .....	27
2.12.3 In-Building Fire Emergency Voice/Alarm Communications Systems (Chapter 24, NFPA 72) .....	28
2.12.4 Combination Systems .....	28
2.12.5 Interconnected Fire Alarm Control Units .....	29
2.12.6 Emergency Communications Systems .....	29
2.12.7 Supervising Station Alarm Systems (Chapter 26, NFPA 72) .....	32
2.12.8 Central Station Service Alarm Systems (Chapter 26, NFPA 72) .....	32
2.12.9 Proprietary Supervising Station Alarm Systems (Chapter 26, NFPA 72) .....	33
2.12.10 Remote Supervising Station Alarm Systems (Chapter 26, NFPA 72) .....	33
2.12.11 Public Emergency Alarm Reporting Systems (Chapter 27, NFPA 72) .....	35

Section 3 Fire Alarm System Concepts .....	37
3.1 General.....	37
3.2 Multiplexing or Networking .....	37
3.3 Circuit Interfaces (Transponders, Data Gathering Panels) .....	38
3.4 Multiplexed or Networked Outputs .....	38
3.5 Addressability .....	40
3.6 Intelligent (Smart) Circuit Interfaces .....	41
3.7 Programming .....	41
3.8 Addressable Devices.....	41
3.9 Multiplexing Technology.....	42
3.10 Active Multiplex.....	42
3.11 Digital Signaling.....	42
3.12 Analog Sensors .....	43
3.13 Intelligent Systems .....	43
3.14 Displays .....	45
3.15 Digital Alarm Communicator Systems (DACS) .....	45
Section 4 Initiating Devices .....	46
4.1 Manual and Automatic Alarm Initiating Devices.....	46
4.2 Manual Fire Alarm Boxes .....	46
4.2.1 Non-Coded Fire Alarm Boxes .....	46
4.2.2 Coded Fire Alarm Boxes .....	46
4.2.3 Pre-signal Fire Alarm Boxes .....	46
4.2.4 General Alarm Fire Alarm Boxes .....	46
4.2.5 Breakglass Fire Alarm Boxes.....	46
4.2.6 Single-action fire alarm boxes.....	47
4.2.7 Double-action fire alarm boxes .....	47
4.3 Automatic Alarm Initiating Devices.....	48
4.3.1 Classification of Automatic Fire Detectors .....	48
4.3.2 Heat-Sensing Fire Detectors.....	50
4.3.3 Smoke Sensing Fire Detectors .....	53
4.4 Switches On Automatic Fire Suppression Systems .....	55
4.4.1 Waterflow Switch on Sprinkler Systems .....	55
4.4.2 Alarm Switches on Fire Suppression Systems .....	55
4.4.3 Supervisory Monitoring for Sprinkler Systems.....	55
4.4.4 Engine Driven Generator Supervision .....	56
4.5 Installation Wiring .....	56
4.6 Pathway Class—Circuit Classes. For Conventional Initiating Device Circuit (IDC).....	60
Section 5 Notification Appliances.....	62
5.1 General.....	62
5.2 Alarm Notification Appliances.....	62
5.3 Audible Alarm Notification Appliances .....	62
5.3.1 Bells .....	62
5.3.2 Horns.....	62

5.3.3	Chimes .....	63
5.3.4	Buzzers .....	63
5.3.5	Sirens .....	63
5.3.6	Speakers .....	63
5.3.7	Electronic Alarms .....	63
5.4	Visible Alarm Notification Appliances .....	64
5.5	Combination Audible/Visible Notification Appliances .....	64
5.6	Exit Marking Audible Notification Appliance .....	64
5.7	Textual Audible Notification Appliance .....	64
5.8	Visible Notification Appliance .....	65
5.9	Textual Visible Notification Appliance .....	65
5.9.1	Visible Annunciators .....	65
5.9.2	Lamp Annunciators .....	65
5.9.3	Drop-Type Annunciators .....	65
5.9.4	Incandescent Lamp .....	65
5.9.5	Solid-State Lamp .....	65
5.9.6	Fluorescent Lamp .....	65
5.10	Permanent Recorders .....	66
5.10.1	Punch Registers .....	66
5.10.2	Print Recorders .....	66
5.10.3	Time Stamps .....	66
5.11	Installation Wiring .....	66
Section 6 Installation Instructions for Fire Alarm Systems .....		69
6.1	General .....	69
6.2	Location of System Components .....	69
6.2.1	General .....	69
6.2.2	Fire Alarm Control Units .....	69
6.2.3	Alarm Initiating Devices .....	69
6.2.4	Audible Alarm Notification Appliances .....	70
6.2.5	Visible Alarm Notification Appliances .....	70
6.2.6	Visible Alarm Signal Annunciators .....	71
6.2.7	Permanent Recorders .....	71
6.2.8	Trouble Signal Appliances .....	71
6.3	Power Supplies .....	71
6.3.1	Number of Sources Required .....	71
6.3.2	Primary (Main) Power Supplies .....	71
6.3.3	Secondary (Standby) Power Supplies .....	72
6.3.4	Batteries .....	73
6.4	Requirements for Installation of Wiring and Equipment .....	73
6.5	Manufacturer's Published Instructions .....	74
6.6	Local Codes .....	74
6.7	Types of Circuits .....	74
6.8	Intermixing of Circuits .....	74

6.8.1	Non-Power-Limited Circuits and Conductors.....	74
6.8.2	Power-Limited Circuits and Conductors (NFPA 70, Article 760-136) .....	74
6.9	Enclosed Versus Exposed Wiring .....	76
6.10	Selecting Conductors and Cables .....	77
6.11	Cable Markings.....	77
6.12	Identification of Circuits .....	77
6.13	Monitoring for Integrity.....	77
6.14	Lightning/Surge Protection (Circuit Protection) .....	78
6.15	Outside Wiring.....	78
Section 7 System Start-Up Procedure .....		79
7.1	General.....	79
7.2	Check of Installation Wiring.....	79
7.2.1	Preliminary .....	79
7.2.2	Test for Extraneous Voltages.....	79
7.2.3	Test for Shorts and Opens.....	79
7.2.4	Test for Grounds .....	82
7.2.5	Visual Inspection .....	82
7.2.6	Check of Power Sources .....	82
7.3	Normal Operation (Normal Monitoring Condition).....	82
7.4	Monitoring of Circuits for Integrity (Electrical Supervision) .....	83
7.4.1	General .....	83
7.4.2	Power Supply Circuits.....	83
7.4.3	Initiating Device and Notification Appliance Circuits.....	83
7.4.4	Overcurrent Protection Devices .....	83
7.4.5	Municipal Circuits .....	83
7.4.6	Supplementary Circuits.....	84
7.4.7	Annunciator Circuits.....	84
7.5	Alarm Operation .....	84
7.6	Authority Having Jurisdiction .....	85
Section 8 Proper Maintenance of Fire Alarm Systems .....		86
8.1	Periodic Maintenance.....	86
8.1.1	General .....	86
8.1.2	System Performance and Integrity.....	86
8.2	Fire Alarm Control Units.....	86
8.2.1	Printed Circuit Board Assemblies of Modules.....	86
8.2.2	Relay Maintenance .....	87
8.2.3	Battery Charger Maintenance .....	87
8.2.4	Battery Maintenance .....	87
8.2.5	Fuses .....	87
8.2.6	Circuit Breakers.....	87
8.2.7	Condition of Control Unit Cabinets (Dust and Dirt Removal).....	87
8.3	Non-Coded Manual Fire Alarm Boxes .....	88
8.4	Coded Manual Fire Alarm Boxes .....	88

8.4.1	General .....	88
8.4.2	Spring-Driven Fire Alarm Boxes .....	88
8.4.3	Motor-Driven Coded Fire Alarm Boxes .....	89
8.5	Automatic Transmitters .....	89
8.6	Automatic Heat Detectors .....	89
8.6.1	Fixed-Temperature Heat Detector .....	89
8.6.2	Rate-of-Rise Heat Detectors .....	89
8.6.3	Rate-Compensation Heat Detectors .....	90
8.6.4	Explosion-Proof Heat Detectors .....	90
8.7	Smoke Detectors .....	90
8.8	Sprinkler Waterflow Detectors .....	90
8.8.1	Pressure Operated .....	91
8.8.2	Vane Operated .....	91
8.9	Gate-Valve Supervisory Contacts .....	91
8.10	Open Stem and Yoke (Os & Y) Valve Supervisory Contacts .....	91
8.11	Pressure Switches .....	91
8.12	Tank Switches for High and Low Alarm Service on Gravity Tanks .....	91
8.13	Differential Pressure Switches .....	92
8.14	Inspector's Test Valves .....	92
8.15	Notification Appliance—Alarm Horns .....	92
8.16	Notification Appliance—Alarm Bells .....	92
8.17	Strobe Notification Appliances .....	93
8.18	Trouble Bells and Buzzers .....	93
8.19	Remote Switches on Systems .....	93

**FIGURES**

Figure 2-1	Fire alarm voice control unit .....	17
Figure 2-2	Examples of fire alarm control units .....	19
Figure 2-3	Two-wire class B initiating device circuit with end-of-line resistor .....	22
Figure 2-4	Four-wire class A initiating device circuit with return run to panel .....	22
Figure 2-5	Two-wire class B notification appliance circuit using polarized DC notification appliances .....	23
Figure 2-6	Two-wire class B audio notification appliance circuit using capacitor-coupled speakers .....	23
Figure 2-7	Four-wire class A notification appliance circuit with return run to panel .....	24
Figure 2-8	Two-wire class B signaling line circuit with T-tap connection .....	25
Figure 2-9	Four-wire class A or class X signaling line circuit .....	25
Figure 2-10	Example of a fire alarm control unit used as a protected premises system .....	27
Figure 2-11	Example of an in-building fire emergency voice/alarm communications system .....	28
Figure 2-12	Emergency communications systems classification .....	30
Figure 2-13	Remote supervising station fire alarm system schematic diagram .....	34
Figure 2-14	Remote supervising station fire alarm system riser diagram .....	34
Figure 2-15	Local energy auxiliary alarm system .....	35
Figure 2-16	Shunt auxiliary alarm system .....	36

Figure 3-1 Basic multiplex system block diagram showing initiating device circuits connected to circuit interfaces and to a signaling line circuit ..... 38

Figure 3-2 Basic multiplex system showing notification appliance circuits also connected to circuit interfaces..... 39

Figure 3-3 Active multiplex system using T-tapped connections..... 40

Figure 3-4 Multiplex system where nonaddressable initiating devices are connected to an addressable initiating device that includes circuit interface..... 44

Figure 4-1 Breakglass fire alarm box..... 47

Figure 4-2 Single-action fire alarm..... 47

Figure 4-3 Double action fire alarm box..... 48

Figure 4-4 An early example of an ionization detector..... 48

Figure 4-5 An example of a current multi-criteria detector..... 48

Figure 4-6 Spot-type example: thermal detector..... 49

Figure 4-7 Spot-type example: smoke detector..... 49

Figure 4-8 Duct smoke detector housing..... 49

Figure 4-9 Fixed temperature detector..... 50

Figure 4-10 Electrical conductivity sensing element..... 50

Figure 4-11 Heat-sensitive cable..... 51

Figure 4-12 Schematic of rate-compensation detector..... 51

Figure 4-13 Combination spot-type rate-of-rise and fixed temperature detector..... 52

Figure 4-14 Pneumatic rate-of-rise tubing..... 53

Figure 4-15 Current flow-through ionization detector sensing chamber..... 53

Figure 4-16 Projected beam smoke detector..... 54

Figure 4-17 Photoelectric light scattering detector..... 54

Figure 4-18 Waterflow switch on sprinkler system..... 55

Figure 4-19 Initiating devices, correctly wired..... 57

Figure 4-20 Initiating devices, incorrectly wired..... 57

Figure 4-21 Pigtail connections, incorrect wiring method..... 58

Figure 4-22 Pigtail connections, correct wiring method..... 58

Figure 4-23 Incorrect wiring method for multiriser initiating device circuit..... 59

Figure 4-24 Correct wiring method for multiriser initiating device circuit..... 59

Figure 4-25 Correct wiring method for class A circuit..... 61

Figure 5-1 Incorrect installation wiring method for a notification appliance circuit..... 67

Figure 5-2 Correct installation wiring method for a notification appliance circuit..... 67

Figure 5-3 Correct installation wiring method for single notification appliance circuit with two risers..... 67

Figure 7-1 End-of-line device on two-wire class B initiating device circuit..... 80

Figure 7-2 End-of-line device in control unit on four-wire class A initiating device circuit..... 80

Figure 7-3 Polarized diode-type notification appliances connected in parallel..... 81

Figure 7-4 Speaker-type notification appliances connected in parallel..... 81

**TABLES**

Table 6-1 Operating periods required by NFPA standards..... 72

Table 7-1 Resistance of conductors..... 81

## FOREWORD

The purpose of this training manual is to provide text material suitable for training persons in the proper physical installation of fire alarm signaling systems. To that end, this manual covers terminology, basic theory of operation, installation details, system startup techniques, and general maintenance.

While the manual may serve as a standalone text, it is best used as a source material for either apprentices or journeymen in a classroom environment using a qualified instructor.

The manual emphasizes installation of basic fire alarm signaling systems instead of how or when to apply the myriad system or equipment options available. Though the manual focuses on installation, the reader is cautioned to follow the specific published installation instructions provided by the manufacturer of systems or equipment being installed.

This information is a technical guide, distinct from mandatory requirements for compliance. It will be updated to keep current with requirements of referenced and/or quoted publications of other organizations. Comments, questions, or recommendations are invited and should be addressed to:

Director, Technical Standards  
National Electrical Manufacturers Association  
1300 N. 17th Street, Suite 900  
Rosslyn, VA 22209

This standards publication was developed by the NEMA Fire, Life Safety, Security, and Emergency Communications Section. At the time it was approved, the committee was composed of the following members:

Apollo America  
Bosch Security Systems  
BRK Brands Inc./First Alert  
Eaton  
Evax Systems, Inc.  
Federal Signal Corporation  
Figaro USA, Inc.  
Gentex Corporation  
Honeywell Fire Systems  
HSI Fire Safety  
Light Engine America  
Micropack Detection  
Nest Labs  
Potter Electric Signal Company, LLC  
SDi LLC  
Siemens Industry, Inc.  
Simplex-Grinnell LP  
Space Age Electronics  
US Electric  
Vicom  
Xtrails Inc.



## Section 1 General

### 1.1 Scope

This manual, developed by the automatic fire detection and alarm industry of the Fire, Life Safety, Security and Emergency Notification Section, provides technical information on basic fire alarm systems in common usage.

This edition of the manual supersedes all prior versions.

Portions of this material are reprinted with permission from the 2013 edition of the National Fire Protection Association's *NFPA 72 National Fire Alarm and Signaling Code*<sup>®</sup>, copyright 2012, National Fire Protection Association, Quincy, Massachusetts. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

### 1.2 Referenced Standards

Acoustical Society of America ANSI/ASA S3.41	<i>American National Standard Audible Emergency Evacuation Signal</i>
International Code Council IBC-2012 IFC-2012	<i>International Building Code</i> <i>International Fire Code</i>
National Electrical Manufacturers Association NEMA SB 50-2014	<i>Emergency Communications Audio Intelligibility Applications Guide</i>
National Fire Protection Association NFPA 13-2013 NFPA 70-2014 NFPA 72-2013 <sup>1</sup> NFPA 101-2015 NFPA 1221-2016 NFPA 5000-2015	<i>Standard for the Installation of Sprinkler Systems</i> <i>National Electrical Code</i> <i>National Fire Alarm Code</i> <i>Life Safety Code</i> <i>Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems.</i> <i>Building Construction and Safety Code</i>
Underwriters Laboratories UL 1971	<i>Signaling Devices for the Hearing Impaired</i>

NOTE: Since NFPA standards and codes are periodically revised, the year of the desired edition of the particular standard or code should be used when referencing the NFPA document involved. Two methods are in common use. One is to reference the code by stating NFPA 72-2013. The other is to refer to the 2013 edition of NFPA 72. If a particular question comes up regarding a standard or code, be sure to correctly identify which edition of the code may be at issue. All states or municipalities that have adopted NFPA codes or standards by reference do not always refer to the latest edition available. Each state or municipality may adopt the NFPA codes in whole or in part. The user should check for local amendments to the codes.

### 1.3 General Definitions

**acknowledge:** To confirm that a message or signal has been received, such as by the pressing of a button or the selection of a software command.