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INDUSTRIAL CONTROL AND SYSTEMS: CONTROL CIRCUIT AND PILOT DEVICES



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NEMA Standards Publication ICS 5

INDUSTRIAL CONTROL AND SYSTEMS CONTROL-CIRCUIT AND PILOT DEVICES

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Table of Contents

Comprehensive Table of Contents iv

Foreword xvii

INTRODUCTION xxi

Part 1

GENERAL STANDARDS FOR CONTROL-CIRCUIT AND PILOT DEVICES 1

1. GENERAL 1
2. DEFINITIONS 2
3. CLASSIFICATION 3
4. CHARACTERISTICS AND RATINGS 3
5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 8
6. SERVICE AND STORAGE CONDITIONS 9
7. CONSTRUCTION 9
8. PERFORMANCE REQUIREMENTS AND TESTS 9
9. APPLICATION 18

Part 2

INDUSTRIAL CONTROL RELAYS 21

1. GENERAL 21
2. DEFINITIONS 21
3. CLASSIFICATION 22
4. CHARACTERISTICS AND RATINGS 23
5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 24
6. SERVICE AND STORAGE CONDITIONS 24
7. CONSTRUCTION 24
8. PERFORMANCE REQUIREMENTS AND TESTS 24
9. APPLICATION 25

Part 3

INDUSTRIAL CONTROL INPUT DEVICES ACTUATED BY FORCE, TEMPERATURE OR PRESSURE 27

1. GENERAL 27
2. DEFINITIONS 27
3. CLASSIFICATION 33

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4. CHARACTERISTICS AND RATINGS 33
5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 34
6. SERVICE AND INSTALLATION CONDITIONS 35
7. CONSTRUCTION 35
8. PERFORMANCE REQUIREMENTS AND TESTS 36
9. APPLICATION 37

Part 4

PROXIMITY SWITCHES 39
1. GENERAL 39
2. DEFINITIONS 41
3. CLASSIFICATION 45
4. CHARACTERISTICS 45
5. PRODUCT INFORMATION 49
6. SERVICE, MOUNTING AND TRANSPORT CONDITIONS 51
7. CONSTRUCTION AND PERFORMANCE REQUIREMENTS 52
8. TESTS 60
9. APPLICATION 80

Part 5

PUSHBUTTONS, SELECTOR SWITCHES, INDICATING LIGHTS AND PUSHBUTTON STATIONS 81
1. GENERAL 81
2. DEFINITIONS 81
3. CLASSIFICATION 81
4. CHARACTERISTICS AND RATINGS 82
5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 82
6. SERVICE AND STORAGE CONDITIONS 83
7. CONSTRUCTION 83
8. PERFORMANCE REQUIREMENTS AND TESTS 85
9. APPLICATION 85

Part 6

MECHANICAL CONTROL-CIRCUIT DEVICES WITH NORMALLY-CLOSED CONTACTS HAVING DIRECT-OPENING ACTION 87
1. GENERAL 87
2. DEFINITIONS 87
3. CLASSIFICATION 87
4. CHARACTERISTICS AND RATINGS 87
5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 88

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6. SERVICE AND STORAGE CONDITIONS 89
7. CONSTRUCTION 89
8. PERFORMANCE AND TESTS 89
9. APPLICATION 91

ANNEX A (Informative)
CLASSIFICATION OF PROXIMITY SWITCHES 93

ANNEX B (Informative)
TYPICAL PROXIMITY SWITCH SPECIFICATIONS 95

ANNEX C (Normative)
PROGRAMMABLE LOGIC CONTROLLERS (PLC) COMPATIBILITY 125

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Comprehensive Table of Contents

Comprehensive Table of Contents iv

Foreword xvii

INTRODUCTION xxi

Part 1

GENERAL STANDARDS FOR CONTROL-CIRCUIT AND PILOT DEVICES 1

1. GENERAL 1
   1.1 Referenced Standards 1
   1.2 Scope 1
   1.3 Normative References 1

2. DEFINITIONS 2

3. CLASSIFICATION 3

4. CHARACTERISTICS AND RATINGS 3
   4.1 AC Mechanical Switching Elements 3
      4.1.1 AC Contact Rating Designations 3
      4.1.2 AC Contact Ratings 3
   4.2 DC Mechanical Switching Elements 4
      4.2.1 DC Contact Rating Designations 4
      4.2.2 DC Contact Ratings 4
   4.3 AC/DC Solid State Switching Elements Ratings 6
   4.4 Contact Characteristics of Dry Reed Switches 8

5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 8
   5.1 Polarity Marking 8
   5.2 Maintenance 9

6. SERVICE AND STORAGE CONDITIONS 9

7. CONSTRUCTION 9
   7.1 Electrical Spacings 9
   7.2 Color Coding of Cord-Connected Devices 9

8. PERFORMANCE REQUIREMENTS AND TESTS 9
   8.1 Control-Circuit Device Connectors for Copper Conductors 9
      8.1.1 General 9

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8.1.2 Performance Tests 9
8.2 Requirements and Tests for Mechanical Switching Elements 10
8.2.1 General 10
8.2.2 Temperature Rise Testing 10
8.2.3 Overload Testing of AC and DC Contacts 10
8.2.3.1 Test Conditions 10
8.2.3.2 Test Criteria 10
8.2.4 Endurance Testing of AC and DC Contacts 10
8.2.4.1 Test Conditions 10
8.2.4.2 Test Criteria 11
8.2.5 Testing of AC Contacts for Abnormal Conditions of Use 11
8.2.6 Test Loads for AC Contacts 11
8.2.7 Inductive Test Loads for DC Contacts 11
8.2.7.1 Construction 12
8.2.7.2 Explanation 15
8.3 Requirements and tests for semiconductor switching elements 15
8.3.1 General 15
8.3.2 Temperature Test 15
8.3.2.1 Test Conditions 15
8.3.2.2 Test Criteria 15
8.3.3 Verification of Make and Break Capability 15
8.3.3.1 Normal Conditions of Use 15
8.3.3.2 Abnormal Conditions of Use 16
8.3.3.3 Test Loads for AC Switching Elements 17
8.3.3.4 Test Loads for DC Switching Elements 17
8.3.3.5 Test Criteria 17

9. APPLICATION 18
9.1 Contact Life 18
9.2 Polarity 18
9.3 Polarity Marking 19
9.4 Component Applications 19
9.5 Control-Circuit-Type Switches 19
9.6 Logic-Type Switches 19
9.7 Arc Suppression 20
9.8 Voltage Variation Requirement for Static Switching Control Elements 20
9.9 Application Considerations 20

Part 2

INDUSTRIAL CONTROL RELAYS 21

1. GENERAL 21
1.1 Scope 21
1.2 Normative References 21

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2. DEFINITIONS 21

3. CLASSIFICATION 22

3.1 Contact Forms 22

3.2 Control Relay and Time-Delay Relay Class Designations 22

4. CHARACTERISTICS AND RATINGS 23

4.1 Relay Coils 23

4.2 Switching Elements 23

4.2.1 Control and Time-Delay Relay Ratings 23

4.2.2 Semiconductor Switching Element Ratings 23

5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 24

6. SERVICE AND STORAGE CONDITIONS 24

7. CONSTRUCTION 24

8. PERFORMANCE REQUIREMENTS AND TESTS 24

8.1 Switching Element Performance Requirements 24

8.1.1 Mechanical Contact Performance 24

8.1.2 Semiconductor Switching Element Performance Requirements 24

8.1.3 Temperature Rise of Contacts 24

8.2 Coil Performance Requirements 24

8.2.1 Range of Coil Operating Voltage 24

8.2.2 Coil Temperature Rise 24

8.3 Terminal Temperature Rise 25

8.4 Dielectric Test 25

8.4.1 Control and Time-Delay Relays with Contacts 25

8.4.2 Time-Delay Relays with Semiconductor Switching Elements 25

9. APPLICATION 25

9.1 Application Guide for Control Relays and Time-Delay Relays with Mechanical Contact Switching Element 25

9.2 Application Guide for Time-Delay Relays Having Semiconductor Switching Elements 26

9.3 Overlapping Contacts 26

Part 3

INDUSTRIAL CONTROL INPUT DEVICES ACTUATED BY FORCE, TEMPERATURE OR PRESSURE 27

1. GENERAL 27

1.1 Scope 27

1.2 Normative References 27

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2. DEFINITIONS 27
2.1 Definitions of Switch Types 27
2.2 Definitions for Limit Switches 30
2.2.1 General Definitions Applying to Limit Switches 30
2.2.2 Definitions Applying to Momentary Contact Limit Switch 31
2.2.3 Definitions Applying to Maintained Contact Limit Switches 31
2.3 Definitions Applying to Pressure Switches 32
2.4 Definitions Applying to Temperature Switches 33

3. CLASSIFICATION 33

4. CHARACTERISTICS AND RATINGS 33
4.1 Electrical Switching Element or Output Ratings 33
4.1.1 Contact Ratings 33
4.1.1.1 Standard-Duty Rating 33
4.1.1.2 Heavy-Duty Rating 33
4.1.1.3 Temperature Switches and Proportional Temperature Controllers Used to Control Noninductive Loads 33
4.1.2 Semiconductor Switching Element Ratings 33
4.2 Pressure Ratings 34
4.2.1 Pressure Switches 34
4.2.2 Pressure Limit Control 34
4.3 Temperature Ratings 34
4.3.1 Temperature Switches 34
4.3.2 Proportional Temperature Controllers 34
4.3.3 Temperature Limit Controls 34
4.3.4 Allowable Temperature Limits 34
4.3.5 Temperature Rating of Conductors 34

5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 34
5.1 Preventative Maintenance 34
5.2 Specific Maintenance Instructions for Float Switches 35

6. SERVICE AND INSTALLATION CONDITIONS 35
6.1 Pressure Switch Service Conditions 35
6.1.1 Chemical 35
6.1.2 Surges 35
6.2 Temperature Switch Service Conditions 35
6.3 Liquid Level Switch Service Conditions 35

7. CONSTRUCTION 35
7.1 Materials for Temperature Switch Actuators 35
7.2 Maintained-Contact Limit Switches 35

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8. PERFORMANCE REQUIREMENTS AND TESTS 36
8.1 Contact Performance 36
8.1.1 Control Circuit Switches 36
8.1.2 Motor Control Switches 36
8.2 Semiconductor Switching Element Performance 36
8.3 Temperature Rise of Terminals 36
8.4 Dielectric Test 37
8.5 Other Requirements 37
8.5.1 Actuators of Pressure Switches 37
8.5.2 Pressure Limit Controls 37
8.5.3 Temperature Limit Control 37

9. APPLICATION 37

Part 4

PROXIMITY SWITCHES 39

1. GENERAL 39
1.1 Scope 39
1.2 Normative References 39
1.3 List of Symbols 40

2. DEFINITIONS 41

3. CLASSIFICATION 45

4. CHARACTERISTICS 45
4.1 Summary Of Characteristics 45
4.1.1 Operation Of An Inductive Or Capacitive Proximity Switch 45
4.1.2 Operation Of An Ultrasonic Proximity Switch 46
4.1.3 Operation Of A Photoelectric Proximity Switch 46
4.1.4 Operation Of A Magnetic Proximity Switch 46
4.2 Operating Conditions 46
4.2.1 Operating Distance(S) Of Inductive And Capacitive Proximity Switches 46
4.2.1.1 Rated Operating Distance S_n 47
4.2.1.2 Sensing Range s_d 47
4.2.2 Operating Distance(S) Of A Photoelectric Proximity Switch 47
4.2.2.1 Sensing Range s_d 47
4.3 Rated (Nominal) And Limiting Values For The Proximity Switch And Switching Element(S) 48
4.3.1 Voltages 48
4.3.1.1 Rated (Nominal) Operational Voltage U_e 48
4.3.1.2 Rated Insulation Voltage U_i 48
4.3.1.3 Rated Impulse Withstand Voltage U_{imp} 48
4.3.1.4 Maximum Voltage Drop U_d 48

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4.3.2 Currents 48
4.3.2.1 Rated Operational Current I_e 48
4.3.2.2 Minimum Operational Current I_m 48
4.3.2.3 OFF-state Current I_r 49
4.3.2.4 No-Load Supply Current I_o 49
4.3.3 Rated Supply Frequency 49
4.3.4 Standard Frequency Of Operation f 49
4.3.5 Normal Load And Abnormal Load Characteristics 49
4.3.5.1 Rated Making And Breaking Capacities And Behavior Of Switching Element Under Normal Conditions 49
4.3.5.2 Making and breaking capacities under abnormal conditions 49
4.3.6 Short-Circuit Characteristics 49
4.3.6.1 Rated Conditional Short-Circuit Current 49
4.4 Utilization Categories For The Switching Element 49

5. PRODUCT INFORMATION 49
5.1 Nature Of Information 49
5.1.1 Identification 50
5.1.2 Specifications 50
5.2 Marking 50
5.2.1 General 50
5.2.2 Terminal Identification And Marking 51
5.2.3 Functional Markings 51
5.3 Instruction For Installation, Operation And Maintenance 51

6. SERVICE, MOUNTING AND TRANSPORT CONDITIONS 51
6.1 Normal Service Conditions (Temperature, Altitude, Climatic) 51
6.1.1 Ambient Air Temperature (Operating Temperature Range) 51
6.1.1.1 Inductive, Capacitive, Magnetic And Ultrasonic Proximity Switches 51
6.1.1.2 Photoelectric Proximity Switch 51
6.1.2 Altitude 51
6.1.3 Climatic Conditions 51
6.1.3.1 Humidity 51
6.1.3.2 Pollution Degree 51
6.2 Conditions During Transport And Storage 51
6.3 Mounting 52

7. CONSTRUCTION AND PERFORMANCE REQUIREMENTS 52
7.1 Construction Requirements 52
7.1.1 Clearances And Creepage Distances 52
7.1.2 Indicating Means 52
7.1.3 Terminals 52
7.1.3.1 Connection Means 52
7.1.3.2 Connection Identification And Marking 52
7.1.4 Provisions For Protective Grounding 52
7.1.5 Enclosure Rating 52

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7.1.6 Physical Dimensions 53
7.2 Performance Requirements 53
7.2.1 Operating Conditions 54
7.2.1.1 General 54
7.2.1.2 Operating Limits 54
7.2.1.3 Operating Distances 54
7.2.1.4 Repeat accuracy, R 57
7.2.1.5 Differential Travel H 57
7.2.1.6 Standard Frequency Of Operation f 57
7.2.1.7 Time Delay Before Availability t_v (Start-Up Time) 57
7.2.1.8 Turn On time t_{on} 57
7.2.1.9 Turn Off Time t_{off} 57
7.2.1.10 Excess Gain, Photoelectric Proximity Switch 57
7.2.1.11 Rated (Nominal) Operational Current I_e 57
7.2.1.12 Minimum Operational Current I_m 57
7.2.1.13 OFF-State Current I_r 58
7.2.1.14 Switching Element Operation 58
7.2.1.15 Voltage Drop U_d 58
7.2.2 Temperature Rise 58
7.2.3 Dielectric Properties 58
7.2.4 Ability To Make And Break 58
7.2.4.1 Making and breaking capacities under normal conditions 58
7.2.4.2 Making And Breaking Capacities Under Abnormal Conditions 59
7.2.5 Conditional Short-Circuit Current 59
7.2.6 Electromagnetic Compatibility (EMC) 59
7.2.6.1 Radiated Electromagnetic Field Withstandability 59
7.2.6.2 Electrostatic Discharge (ESD) Withstandability 59
7.2.6.3 Fast Transient Withstandability 59
7.2.6.4 Emission Requirements 59
7.2.7 Shock And Vibration 60
7.2.7.1 Shock 60
7.2.7.2 Vibration 60
7.2.7.3 Results to be obtained 60

8. TESTS 60
8.1 Kinds Of Tests 60
8.1.1 General 60
8.1.2 Type tests 60
8.1.3 Routine Tests 61
8.2 Compliance With Construction Requirements 61
8.3 Testing Procedures 61
8.3.1 Test Sequences 61
8.3.2 General Test Conditions 62
8.3.2.1 General Requirements 62
8.3.2.2 Evaluation Of Test Result 63
8.3.3 Performance Under No Load, Normal Load And Abnormal Load Condition 63
8.3.3.1 Operation 63
8.3.3.2 Operating Limits 63
8.3.3.3 Temperature Rise 67
8.3.3.4 Dielectric Properties 67

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8.3.3.5 Making And Breaking Capacities 68
8.3.4 Performance Under Short-Circuit Current Conditions 69
8.3.4.1 Test Circuit And Test Procedure 69
8.3.4.2 Results To Be Obtained 70
8.4 Operating Distances 70
8.4.1 Inductive, Magnetic, Capacitive And Ultrasonic Proximity Switches 70
8.4.1.1 Test Conditions 70
8.4.1.2 Effective Operating Distance s_r 71
8.4.1.3 Differential Travel H 71
8.4.1.4 Usable Operating Distance s_u 71
8.4.1.5 Repeat Accuracy R 71
8.4.2 Photoelectric Proximity Switches 71
8.4.2.1 Testing Of The Sensing Range s_d 71
8.4.2.2 Through Beam (Type T) 71
8.4.2.3 Retroreflective (Type R) 72
8.4.2.4 Diffuse Reflective (Type D) 72
8.4.2.5 Results To Be Obtained 72
8.5 Standard Frequency Of Operation 72
8.5.1 Inductive, Magnetic And Capacitive Proximity Switches 72
8.5.2 Ultrasonic Proximity Switches 74
8.5.3 Photoelectric Proximity Switches 77
8.5.3.1 Measurements Means 78
8.5.3.2 Measurement Of Turn On Time (t_{on}) 78
8.5.3.3 Measurement Of Turn Off Time t_{off} 78
8.5.3.4 Results To Be Obtained 78
8.6 Electromagnetic Compatibility 79
8.6.1 Electromagnetic Field Withstandability 79
8.6.2 Electrostatic Discharge Withstandability 79
8.6.3 Fast Transient Withstandability 79
8.6.4 Emission Requirements 79

9. APPLICATION 80

Part 5

PUSHBUTTONS, SELECTOR SWITCHES, INDICATING LIGHTS AND PUSHBUTTON STATIONS 81

1. GENERAL 81
1.1 Scope 81
1.2 Normative References 81

2. DEFINITIONS 81
2.1 General Definitions 81
2.2 Pushbutton Definitions 81

3. CLASSIFICATION 81
3.1 Standard-Duty Pushbutton Stations 81

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3.2 Heavy-Duty Pushbutton Stations 82

4. CHARACTERISTICS AND RATINGS 82
4.1 Contact Ratings 82
4.1.1 Contact Ratings 82
4.1.2 Standard-Duty Pushbuttons and Selector Switches 82
4.1.3 Heavy-Duty Pushbuttons and Selector Switches 82
4.2 Indicating Light Ratings 82
4.3 Selector Switch Characteristics 82

5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 82

6. SERVICE AND STORAGE CONDITIONS 83

7. CONSTRUCTION 83
7.1 Color Coding of Pushbuttons 83
7.2 Direction of Operation of Selector Switches 83
7.2.1 Rotary Selector Switches 83
7.2.2 Straight-Line Motion Selector Switches 83
7.3 Legends for Pushbutton Stations 84
7.4 Arrangement of Elements in Pushbutton Stations 84
7.4.1 Stop Button Location 84
7.4.2 Arrangement of Pushbutton Stations for Multispeed Motor Controllers 85

8. PERFORMANCE REQUIREMENTS AND TESTS 85
8.1 Contact Performance 85

9. APPLICATION 85
9.1 Contact Life 85
9.1.1 General 85
9.1.2 Long Cycle Life 85
9.1.3 Solenoid Control Circuits 85
9.2 Overlapping Contacts 85

Part 6

MECHANICAL CONTROL-CIRCUIT DEVICES WITH NORMALLY-CLOSED CONTACTS HAVING DIRECT-OPENING ACTION 87

1. GENERAL 87
1.1 Scope 87
1.2 Normative References 87

2. DEFINITIONS 87

3. CLASSIFICATION 87

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4. CHARACTERISTICS AND RATINGS 87
4.1 Contact Ratings 87
4.1.1 AC Ratings 87
4.1.2 DC Ratings 87

5. PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION 88
5.1 Markings on the Device 88
5.2 Additional Information 88

6. SERVICE AND STORAGE CONDITIONS 89

7. CONSTRUCTION 89
7.1 Multiple Contacts 89
7.2 Contact Element Types 89

8. PERFORMANCE AND TESTS 89
8.1 Verification Of Direct-Opening Action 89
8.2 Mechanical Operation Of Limit Switches With Direct-Opening Action Contacts At Temperature Extremes 89
8.3 Robustness Of Direct-Opening Action 90
8.4 Conditional Short-Circuit Test 90
8.4.1 General Conditions For Short-Circuit Test 90
8.4.2 Test procedure 90
8.4.3 Test Circuit And Test Quantities 90

9. APPLICATION 91

ANNEX A (Informative)
CLASSIFICATION OF PROXIMITY SWITCHES 93

ANNEX B (Informative)
TYPICAL PROXIMITY SWITCH SPECIFICATIONS 95
B.1 Type I_A, Inductive cylindrical proximity switches with threaded barrel 95
B.1.1 Dimensions of Type I_A 95
B.1.2 Rated operating distances for Type I_A 96
B.1.3 Installation (mounting) of Type I_A 96
B.1.4 Standard frequency of operation, *f*, of Type I_A 97
B.2 Type I_B, Inductive cylindrical proximity switches with smooth barrel 98
B.2.1 Dimensions of Type I_B 98
B.2.2 Rated operating distances for Type I_B 99
B.2.3 Installation (mounting) of Type I_B 100
B.2.4 Standard frequency of operation *f* of Type I_B 100
B.3 Type I_C, Inductive rectangular proximity switches with square cross section 101

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B.3.1 Dimensions of Type I_C 101
B.3.1.1 Type I1C26 inductive, embeddable, 26 mm x 26 mm 101
B.3.1.2 Type I2C35 inductive, nonembeddable, 35 mm x 35 mm 102
B.3.1.3 Type I2C30 inductive, nonembeddable and Type I1C30 inductive embeddable 30 x 30 mm 103
B.3.1.4 Type I2C40 inductive, nonembeddable and Type I1C40 inductive embeddable 40 x 40 mm 104
B.3.2 Rated operating distances for Type I_C 104
B.3.3 Installation (mounting) of Type I_C 105
B.3.3.1 Type I1C proximity switch installed in damping material 105
B.3.3.2 Type I2C proximity switch installed in damping material 106
B.3.4 Standard frequency of operation *f* of Type I_C 108
B.4 Type I_D, Inductive rectangular proximity switches with rectangular cross-section 108
B.4.1 Dimensions of Type I_D 108
B.4.2 Rated operating distances for Type I_D 109
B.4.3 Installation (mounting) of Type I_D 110
B.4.4 Standard frequency of operation *f* of Type I_D 110
B.5 Type C_A, Capacitive cylindrical proximity switches with threaded barrel 111
B.5.1 Dimensions of Type C_A 111
B.5.2 Rated operating distance s_n for Type C_A 111
B.5.3 Installation (mounting) of Type C_A 112
B.5.4 Standard frequency of operation *f* of Type C_A 112
B.6 Type C_C, Capacitive rectangular proximity switches with square cross section 114
B.6.1 Dimensions of Type C_C 114
B.6.2 Rated operating distances s_n for Type C_C 116
B.6.3 Installation (mounting) of Type C_C 117
B.6.4 Standard frequency of operation *f* of Type C_C 117
B.7 Type C_D, Capacitive rectangular proximity switches with rectangular cross-section 117
B.7.1 Dimensions of Type C_D 117
B.7.2 Rated operating distance s_n for Type C_D 118
B.7.3 Installation (mounting) of Type C_D 119
B.7.4 Standard frequency of operation *f* of Type C_D 119
B.8 Type U_A, Threaded barrel ultrasonic cylindrical proximity switches 120
B.8.1 Dimensions of Type U_A 120
B.8.2 Sensing range of Type U_A 120
B.8.3 Installation (mounting) of Type U_A 121
B.8.4 Standard frequency of operation *f* of Type U_A 121
B.9 Type U_C, Ultrasonic rectangular proximity switches with square cross-section 121
B.9.1 Dimensions of Type U_C 121
B.9.2 Sensing range for Type U_C 122
B.9.3 Installation (mounting) of Type U_C 122
B.9.4 Standard frequency of operation *f* of Type U_C 122
B.10 Type U_D, Ultrasonic rectangular proximity switches with rectangular cross-section 123
B.10.1 Dimensions of Type U_D 123

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B.10.2 Sensing range of Type U_D 124
B.10.3 Installation (mounting) 124
B.10.4 Standard frequency of operation *f* of Type U_D 124

ANNEX C (Normative)
PROGRAMMABLE LOGIC CONTROLLERS (PLC) COMPATIBILITY 125
C-1 General 125
C-2 ON-State Requirements 126
C-3 OFF-State Requirements 127

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Foreword

This Standards Publication was prepared by a technical committee of the NEMA Industrial Control and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes the indicated NEMA Standards Publication. This Standards Publication supersedes ICS 5-1983 (R 1988).

This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors which are vital o a safe installation:

a. Environmental conditions
b. System design
c. Equipment selection and application
d. Installation
e. Operating practices
f. Maintenance

This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and properly maintained, the hazards to persons and property will be reduced.

To continue to serve the best interests of users of Industrial Control and Systems equipment, the Industrial Control and Systems Section is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, olerances, or performance specifications.

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Proposed revisions to this Standards Publication should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, Virginia 22209

This standards publication was developed by the Industrial Control and Systems Section. Section Approval of the standard does not necessarily imply that all section membersw voted for its approval or participated in its developmnet. At the time it was approved, the Section was composed of the following members:

ABB Control, Inc.—Wichita Falls, TX
AEG Automation Systems Corporation—Pittsburgh, PA
Allen-Bradley Company—Milwaukee, WI
Amerace Electronics Components—Punta Gorda, FL
Automatic Switch Company—Florham Park, NJ
Balluff, Inc.—Florence, KY
USD Products, Bussman, Div. of Cooper Ind.—Chicago, IL
CEGELEC Automation—Macon, GA
Eaton Corporation, Cutler-Hammer Products—Milwaukee, WI
Echelon—Palo Alto, CA
Electrical Power Systems, Inc.—Tulsa, OK
Electro Switch Corporation—Weymouth, MA
Elliott Control Company—Hollister, CA
Emerson Electric Company—Grand Island, NY
Entrelec, Inc.—Irving, TX
Firetrol, Inc.—Cary, NC
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Harnischfeger Corporation—Milwaukee, WI
Honeywell, Inc.—Ft. Washington, PA
Hubbell Incorporated—Madison, OH
Joslyn Clark Controls, Inc.—Lancaster, SC
Killark-Stahl, Inc.—St. Louis, MO
Klockner-Moeller Corporation—Franklin, MA
Lexington Switch & Controls—Madison, OH
Master Controls Systems, Inc.—Lake Bluff, IL
Metron, Inc.—Denver, CO
Micro Switch (Div. of Honeywell)—Freeport, IL
Omron Electronics, Inc.—Schaumburg, IL
Onan Corporation—Minneapolis, MN
OZ Gedney, Unit of General Signal Corp.—Brooklyn, NY
Pepperl & Fuchs, Inc.—Twinsburg, OH
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INTRODUCTION

The standards pertaining to control-circuit devices in NEMA Standards Publication ICS 5 are found in six Parts subdivided into the following clauses:

1 **General**
Referenced Standards
Scope
Normative References

2 **Definitions**
Terms which supplement the IEC International Electrical Vocabulary (IEV 441) or assist in clarifying the product standard.

3 **Classification**
Product classifications where they have been established.

4 **Characteristics and Ratings**
Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.

5 **Product Marking, Installation and Maintenance Information**
Product information to be provided to assist the user in the installation, use and maintenance of the devices.

6 **Service and Storage Conditions**
A description of service and storage conditions for which the devices are intended.

7 **Construction**
Marking, color coding and similar production requirements to be incorporated into the product as manufactured, as well as production test requirements where they have been established, i.e., the rules that the manufacturer follows in producing the product.

8 **Performance Requirements and Tests**
The performance required to pass each design test specified for the product.

9 **Application**
Information and performance considerations of importance to those who specify or use the product.

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The standards for the products included within the scope of the Industrial Control and Systems Section are organized as follows:

NEMA Standards Title
Publication No.

ICS 1-1993 Industrial Control and Systems
General Requirements

ICS 2-1993 Industrial Control and Systems
Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC

Part 1: General Standards for Manual and Magnetic Controllers
Part 2: AC Noncombination Magnetic Motor Controllers, Rated 600 Volts
Part 3: Nonmagnetic Motor Controllers
Part 4: Overload Relays
Part 5: DC General-Purpose Constant-Voltage Controllers
Part 6: AC Combination Motor Controllers
Part 7: Magnetic Lighting Contactors

ICS 3-1993 Industrial Control and Systems
Factory-built Assemblies

Part 1: Motor Control Centers Rated Not More Than 600 Volts AC
Part 2: Medium Voltage Controllers Rated 2001 to 7200 Volts AC
Part 3: AC General-Purpose Controllers for Synchronous Motors

ICS 4-1993 Industrial Control and Systems
Terminal Blocks

ICS 5-1993 Industrial Control and Systems
Control Circuit and Pilot Devices

Part 1: General Standards for Control Circuit and Pilot Devices
Part 2: Industrial Control Relays
Part 3: Industrial Control Input Devices Actuated by Force, Temperature and Pressure
Part 4: Proximity Switches
Part 5: Pushbuttons, Selector Switches, Indicating Lights and Pushbutton Stations
Part 6: Mechanical Control-Circuit Devices With Normally-Closed Contacts Having Direct-Opening Action

ICS 6-1993 Industrial Control and Systems
Enclosures

ICS 7-1993 Industrial Control and Systems
Adjustable Speed Drives

Part 1: General Standards for Drive Converters, Drives, and Drive Systems
Part 2: Loop Position and Tension Control Drive Systems
Part 3: Wind and Unwind Drive Systems
Part 4: Variable-Frequency, Three-Phase Controllers, Rated Not More Than 600 Volts
Part 5: Adjustable-Voltage Packaged-Drive Systems (Where DC Armature Power Is Obtained from AC Lines Using Controlled Semiconductor Rectifiers)

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Part 6: Variable-Frequency Drive Systems Rated Not More Than 600 Volts Using Semiconductor Power Conversion
Part 7: Variable-Frequency. Three-Phase Drives, Rated 601 to 7,200 Volts

ICS 8-1993 Industrial Control and Systems
Crane and Hoist Controllers

Part 1: General Standards for Crane Controllers Rated 600 Volts or Less AC and DC
Part 2: Constant-Voltage DC Magnetic Controllers for Motors on Cranes
Part 3: Adjustable-Voltage DC Controllers for Motors on Cranes
Part 4: Magnetic Controllers for AC Wound-Rotor Motors on Cranes
Part 5: Static Controllers for AC Wound-Rotor Motors on Cranes
Part 6: Crane and Hoist Power-Circuit Limit Switches
Part 7: Heavy-Duty DC Magnetic Contactors Rated 600 Volts

ICS 9-1993 Industrial Control and Systems
Power Circuit Accessories

Part 1: Electromagnetic Brakes
Part 2: Resistors and Rheostats
Part 3: Autotransformers and Reactors

ICS 10-1993 Industrial Control and Systems
AC Transfer Switch Equipment

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Part 1
GENERAL STANDARDS FOR CONTROL-CIRCUIT AND PILOT DEVICES

1 GENERAL

1.1 Referenced Standards

In this NEMA Standards Publication reference is made to the standards listed below. Copies are available from the indicated sources.

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, Virginia 22209

DC 2-1982 (R1988)	*Quick Connect Terminals*
ICS 11-993	*Industrial Control and Systems General Requirements*
ICS 1.1-1984 (R1988)	*Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control*
ICS 1.3-1986 (R1991)	*Preventive Maintenance of Industrial Control and Systems Equipment*
ICS 6-1993	Industrial Control and Systems *Enclosures*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 353-1989	*Limit Controls*
UL 486E-1988	*Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors*
UL 508-1994	*Industrial Control Equipment*
UL 698-1991	*Industrial Control Equipment for Use in Hazardous (Classified) Locations*
UL 873-1991	*Temperature-Indicating and Regulating Equipment*

1.2 Scope

The standards in this part apply to general-purpose mechanical, electromechanical and solid-state devices which are principally used in industrial applications for control-circuit switching and the control of solenoids rated not more than 600 volts.

1.3 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1 and ICS 6 also apply to this part unless otherwise stated.

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2 DEFINITIONS

For the purposes of this part the following definitions apply.

abnormal conditions of use: Situations where an electromagnet, although energized, has failed to close, or where a transformer core is saturated. A control-circuit switch is required to break the current corresponding to such abnormal condition of use.

conditions of use: The principal load-switching application of a control-circuit switch as indicated for the various utilization categories in Table 1-4-3.

dry reed switch: A switching device comprised of two or more ferromagnetic reed-like contact-carrying arms which are sealed in a nonmagnetic capsule, usually a glass tube, without the presence of a liquid.

The free end(s) are actuated by a change in a magnetic field, making or breaking electrical contact.

fanout: A rating given to one pole of a coil-operated switching device which represents the maximum number of coils of identical devices which can be controlled in parallel by that pole.

form "A" contacts: A contact arrangement which has single-pole, single throw, normally open contacts. The function of this arrangement is to close a circuit when actuated.

form "B" contacts: A contact arrangement which has single-pole, single throw, normally closed contacts. The function of this arrangement is to open a circuit when actuated.

form "C" contacts: A contact arrangement which has single-pole, double throw contacts with three terminals, one for normally open, one for normally closed and one common. The function of this arrangement is to transfer a circuit when actuated.

form "Z" contacts: A contact arrangement which has single-pole, double-throw contacts with four terminals, two for normally open and two for normally closed. The function of this arrangement is to open one circuit and close the other.

mercury-wetted reed switch: Similar to a dry reed switch except that the contacts are wetted by a film of mercury.

normal conditions of use: Use of a control-circuit switch to close, maintain and open circuits which contain an electromagnet, the magnetic circuit of which is open at the time when the coil current is made and closed when the coil current is broken.

off-state current (I_r): The current which flows through the load when the device is in the off-state.

on-state voltage drop (U_d): The voltage measured across the semiconductor switching element in the on-state at a stated current.

rated insulation voltage (U_i): The value of voltage to which dielectric voltage tests and creepage distances are referred. For equipment not having a specified rated insulation voltage, the highest value of any rated voltages is considered to be the rated insulation voltage.

rated minimum operational current (I_m): The current that is necessary to maintain on-state conduction of the switching element.

rated operational current (I_e): A value I_e of current which determines the application of the switching element. It is assigned by the manufacturer and takes into account the rated operational voltage, the rated supply frequency, and the utilization category. A switching element shall be assigned a number of combinations of rated operational voltage and rated operational current. The rated operational current is stated in relation to the utilization category.

rated operational voltages (U_e): A value U_e of voltage, assigned by the manufacturer, which, in combination with a rated operational current, determines the application of the switching element and to which the utilization categories are referred.

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Utilization category: The utilization category of an equipment defines the intended application of a product. Each utilization category is characterized by the values of currents, voltages, power-factors or time-constants and other data specified in this standard.

3 CLASSIFICATION

See product parts of this publication for classifications.

4 CHARACTERISTICS AND RATINGS

4.1 AC Mechanical Switching Elements

4.1.1 AC Contact Rating Designations

In contact rating designations, the letter (not to be confused with the contact arrangement form letter shown in Clause 2) designates the continuous current-carrying thermal capability of the unit or assembly.

The numerical suffix designates the maximum voltage design values of 600, 300 and 150 volts for suffixes 600, 300 and 150, respectively.

4.1.2 AC Contact Ratings

The ratings and designations of contacts which make, break or carry AC shall be in accordance with Table 1-4-1 for 50 and 60 hertz.

For ratings at voltages between the maximum design value and 120 volts, the make and break ratings shall be obtained by dividing the voltampere rating by the application voltage. For voltages below 120 volts, the maximum make current shall be the same as that for 120 volts, and the maximum break current shall be obtained by dividing the break voltamperes by the application voltage but shall not exceed the continuous thermal test current.

The maximum make values (current and voltamperes) are for the very short duration (30 milliseconds or less) involved in controlling an electromagnetic device. Make and break ratings apply for double-throw contacts only where both the normally open and normally closed contacts are connected to the same polarity.

The ratings given in Table 1-4-1 shall not be exceeded where applied to control-circuit devices.

Caution:

a. In most circumstances, the contacts of control-circuit devices are applied at values less than their make and break ratings. See Clause 9 of this part and other parts of ICS 5 for application guidelines.

b. Contacts for control circuit devices covered by this standard may not be intended for use at very low voltages or currents and may not be suitable for such service. Seek the advice of the manufacturer for such applications.

c. Very low voltage or currents may be defined as being less than the value shown on a log-log-graph chart by a line through one milliampere-350 volts, 50 milliamperes-28 volts, and one ampere-4 volts. See Figure 1-4-1.

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Table 1-4-1
Mechanical Switching Ratings and Test Values for AC Control-Circuit Contacts at 50 or 60 Hertz (see 4.1.2)

Contact Rating Designation	Thermal Continuous Test Current, Amperes	Maximum Current, Amperes								Voltamperes	
		120 Volts		240 Volts		480 Volts		600 Volts			
		Make	Break	Make	Break	Make	Break	Make	Break	Make	Break
A150	10	60	6.00	...	...	...	...	...	...	7200	720
A300	10	60	6.00	30	3.00	...	...	...	...	7200	720
A600	10	60	6.00	30	3.00	15	1.50	12	1.20	7200	720
B150	5	30	3.00	...	...	...	...	...	...	3600	360
B300	5	30	3.00	15	1.50	...	...	...	...	3600	360
B600	5	30	3.00	15	1.50	7.5	0.75	6	0.60	3600	360
C150	2.5	15	1.5	...	...	...	...	...	...	1800	180
C300	2.5	15	1.5	7.5	0.75	...	...	...	...	1800	180
C600	2.5	15	1.5	7.5	0.75	3.75	0.375	3.00	0.30	1800	180
D150	1.0	3.60	0.60	...	...	...	...	...	...	432	72
D300	1.0	3.60	0.60	1.80	0.30	...	...	...	...	432	72
E150	0.5	1.80	0.30	...	...	...	...	...	...	216	36

4.2 DC Mechanical Switching Elements

4.2.1 DC Contact Rating Designations

In contact rating designations, the letters N through R (not to be confused with the contact arrangement form letter defined in Clause 2) designates the continuous current-carrying thermal capability of the unit or assembly. The numerical suffix designates the maximum voltage design values of 600, 300 and 150 volts for suffixes 600, 300 and 150, respectively.

4.2.2 DC Contact Ratings

The ratings and designations of contacts which make, break or carry DC shall be in accordance with Table 1-4-2.

For ratings at 300 volts or less, the make and break ratings shall be obtained by dividing the voltampere rating by the application voltage but shall not exceed the continuous thermal test current.

Make and break ratings apply for double-throw contacts only when both the normally open and normally closed contacts are connected to the same polarity.

The ratings given in Table 1-4-2 shall not be exceeded where applied to control-circuit devices.

Caution:

a. In most circumstances, the contacts of control-circuit devices are applied at values less than their make and break ratings. See Clause 9 and the parts of this publication relating to specific control circuit devices.

b. Contacts for control circuit devices covered by this standard may not be intended for use at very low voltages or currents and may not be suitable for such service. Seek the advice of the manufacturer for such aplications.

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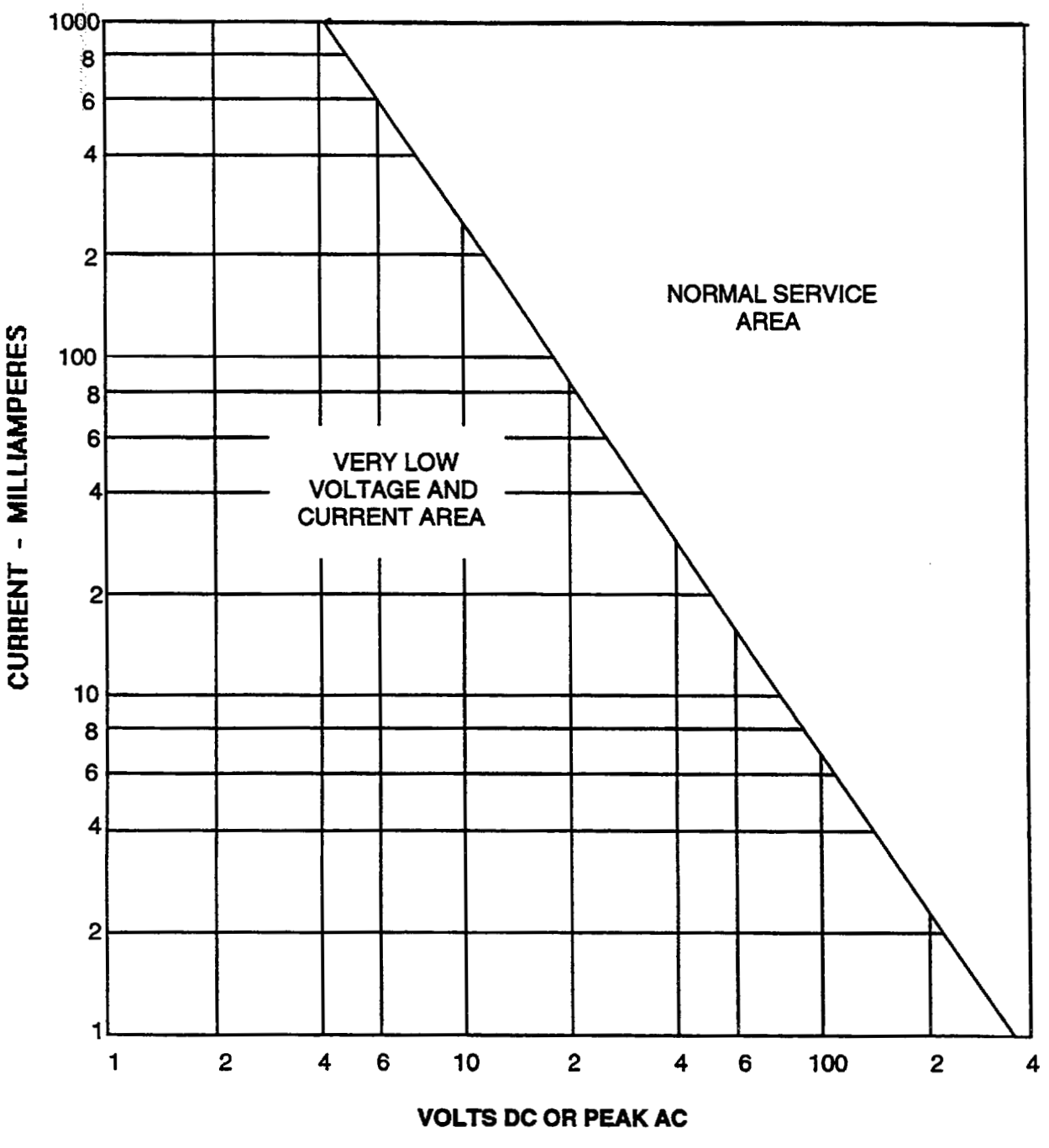


Figure 1-4-1
VERY LOW VOLTAGE AND CURRENT VALUES

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c. Very low voltage or currents may be defined as being less than the value shown on a log-log graph chart by a line through one milliampere-350 volts, 50 milliamperes-28 volts, and one ampere-4 volts. See Figure 1-4-1.

Table 1-4-2
Mechanical Switching ratings and Test Values for DC Control-Circuit Contacts (see 4.2.2)

Contact Rating Designation	Thermal Continuous Test Current, Amperes	Maximum Make or Break Current, Amperes			Voltamperes
		125 Volts	250 Volts	301 to 600 Volts	
N150	10	2.2	...	...	275
N300	10	2.2	1.1	...	275
N600	10	2.2	1.1	0.40	275
P150	5.0	1.1	...	...	138
P300	5.0	1.1	0.55	...	138
P600	5.0	1.1	0.55	0.20	138
Q150	2.5	0.55	...	...	69
Q300	2.5	0.55	0.27	...	69
Q600	2.5	0.55	0.27	0.10	69
R150	1.0	0.22	...	....	28
R300	1.0	0.22	0.11	...	28

4.3 AC/DC Solid State Switching Elements Ratings

The rating of a semiconductor switching element shall include:

a. The utilization category
b. The rating designation
c. The rated operational voltage, U_e

Standard utilization categories are given in Table 1-4-3.

Ratings of semiconductor control circuit switching elements shall be in accordance with Table 1-4-4 for AC ratings and Table 1-4-5 for DC ratings.

In the alphanumeric rating designations, the first letter, S, designates a semiconductor switching element. The second letter designates the rated operational current.

Semiconductor switching elements may have a rated operational current less than shown in Tables 1-4-4 and 1-4-5 for operation in higher ambient temperatures.

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Table 1-4-3
Utilization Categories for Switching Elements

Kind of Current	Category	Typical Applications
Alternating Current	AC-12	Control of resistive loads and solid state loads with optical isolation.
	AC-13	Control of solid state loads with transformer isolation
	AC-14	Control of small electromagnetic loads (max. 72 VA closed)/
	AC-15	Control of electromagnetic loads (greater than 72 VA closed).
Direct Current	DC-12	Control of resistive loads and solid state loads with optical isolation.
	DC-13	Control of electromagnets
	DC-14	Control of electromagnet loads having economy resistors in circuit

Table 1-4-4
Ratings for AC Semiconductor Control-Circuit Switching elements at 50 or 60 Hertz*, **

Switching Element Rating Designation	Rated Operational Current, I_e Amperes†	Rated Make Current, Amperes				Rated Minimum operation Current Ampereres
		AC-15	AC-14	AC-13	AC-12	
SA	10	100	60	20	10	0.1
SB	5	50	30	10	5	0.1
SC	2	20	12	4	2	0.1
SD	1	10	6	2	1	0.05
SE	0.5	5	3	1	0.5	0.02
SF	0.25	2.5	1.5	0.5	0.25	0.01
SG	0.1	1	0.6	0.2	0.1	0.01

* Rated operational voltage shall be specified by the manufacturer as with:

a. Utilization voltage, with a tolerance of +10, -15%. Preferred utilization voltages are 24, 48, 120, and 240 V AC Rated insulation voltage of devices specified in this manner shall be based on operational voltage.

b. Minimum and maximum voltage Rated Insulation Voltage of devices specified in this manner shall be based on the maximum voltage

** Maximum RMS ON-State voltage drop and OFF-State RMS current shall be specified by the manufacturer. This maximum value shall include all combinations of operating current, voltage, and temperature.

† When the operational current rating is based on the use of a user furnished external heat sink or mounting means, the manufacturer shall clearly identify this requirement.

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Table 1-4-5
Ratings for DC Semiconductor Control-Circuit Swtiching Elements* **

Switching Element Rating Designation	Rated Operational Current, I_e† Amperes	Rated Make Current, Amperes DC-14	DC-13	DC-12
SN	10	100	10	10
SP	5	50	5	5
SQ	2	20	2	2
SR	1	10	1	1
SS	0.5	5	0.5	0.5
ST	0.25	2.5	0.25	0.25
SU	0.1	1	0.1	0.1
SV	0.05	0.5	0.05	0.05

* Rated operational voltage shall be specified by the manufacturer as either:

a. Utilization voltage, with a tolerance range of +10, -15%. Preferred utilization voltages are 24, 48, 125, 250 VDC. Rated insulation voltage of devices specified in this manner shall be based on rated operational voltage

b. Minimum and maximum voltage. Rated insulation voltage of devices specified in this manner shall be based on the maximum voltage.

** Maximum ON-State voltage drop and OFF-State current shall be specified by the manufacturer. This maximum value shall included all combinations of operating current, voltage, and temperature.

† When the operational current is based on the use of a user furnished external heat sink or mounting means, the manufacturer shall clearly identify this requirement.

4.4 Contact Characteristics of Dry Reed Switches

See Table 1-4-6 for contact characteristics of dry reed switches.

Table 1-4-6
Dry Reed Contact Characteristics

Characteristic	Contacts: Control-Circuit Type	Contacts: Logic Type
Nature of Rating	Contacts rated fro make, break and carry amperes at a specified voltage	Contacts rated in volt-amperes, maximum voltage and maximum current
Type of Load	Contacts Rated for an inductive load	Contacts rated for a resistive load and, when coil operated, in number of coils which the device can operate (fanout).
Standard Ratings	Contact ratings are shown in 4.1.1 and 4.2.1	Great variety of sizes and contact ratings available appears to make standardization difficult.

5 PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION

5.1 Polarity Marking

Where the contacts of a control-circuit device are not suitable for use on opposite polarity, the manufacturer shall designate these contacts as being suitable for use only on the same polarity.

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.2 Maintenance

See NEMA Standards Publication ICS 1.3 for general maintenance instructions.

6 SERVICE AND STORAGE CONDITIONS

See ICS 1, Clause 6 for standard service and installation conditions.

7 CONSTRUCTION

7.1 Electrical Spacings

See ICS 1, Clause 7 for electrical spacing requirements.

7.2 Color Coding of Cord-Connected Devices

The color coding used in multiconductor cables to identify the terminals associated with the contacts of a factory-wired, cord-connected control-circuit device shall be in accordance with Table 1-7-1. Where an insulated grounding conductor is supplied, it shall be green or green with one or more yellow stripes.

Table 1-7-1
Conductor Color in Multiconductor Cable

Contact Arrangement	When Insulated Grounding Conductor is Provided		When Insulated Grounding Conductor is NOT Provided	
	Conductors	Color	Conductors	Color
A or B	3	Black, White, Green	2	Black, White
C	4	Black, White, Red*, Green	3	Black, White, Red*
Z or two A's or two B's	5	Black, White, Red, Orange, Green	4	Black, White Red Orange

* For Form C contact arrangements, Red identifies the common terminal.

8 PERFORMANCE REQUIREMENTS AND TESTS

8.1 Control-Circuit Device Connectors for Copper Conductors

8.1.1 General

This subclause establishes performance and test values for noninsulated slotted head, screw-tightened pressure wire connectors provided as an integral part of equipment and intended for the field wiring of 14 AWG and smaller copper control-circuit conductors.

The dimensions and performance requirements of quick-connect terminals are given in NEMA Standards Publication DC 2.

The purpose of these tests is to verify the ability of the connector and the device to which it is attached to adequately retain and support conductors.

8.1.2 Performance Tests

The connectors shall be evaluated in accordance with UL 486E and shall meet the temperature rise equirements of ICS 1, Clause 8 when torqued to a value of 7 pound-inches (0.77 N•m).

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Other values of torque shall be permitted to be used for the evaluation provided the equipment is marked with the torque value.

8.2 Requirements and Tests for Mechanical Switching Elements

8.2.1 General

The following design tests shall be used to demonstrate conformance with these standards but are not contemplated in normal production. The device containing the contacts being tested shall be mounted in its enclosure as it is intended to be used in service. Adjacent poles shall be connected with opposite polarity for testing unless polarity restrictions are marked on the device.

Devices with letter designation A (not to be confused with the form letter shown in Clause 2) shall be tested with 14 AWG copper wire, designation B with 20 AWG copper wire and designations C, D, and E with 22 AWG copper wire.

Devices with letter designation N shall be tested with 14 AWG copper wire, designation P with 20 AWG copper wire and designations Q and R with 22 AWG copper wire.

8.2.2 Temperature Rise Testing

Where tested without making or breaking current, a device with a contact rating described in this subclause shall be capable of carrying thermal continuous test current without exceeding the allowable temperature rises given in ICS 1, Clause 8. All poles of the same mode shall be wired in series with 8 feet (2.4 meters) of wire between poles (4 feet or 1.2 meters per terminal).

8.2.3 Overload Testing of AC and DC Contacts

8.2.3.1 Test Conditions

The overload test shall consist of 50 operations of making and breaking 110 percent of the maximum make and break amperes shown in Tables 1-4-1 and 1-4-2 at 110 percent of each applicable voltage. The fifty operations shall be evenly spaced and shall be performed at the rate of six operations per minute. The circuit controlled by the contacts shall be closed for approximately 1 second during each operation.

8.2.3.2 Test Criteria

There shall be no electrical or mechanical failure of the device, nor any undue burning, pitting or welding of the contacts.

8.2.4 Endurance Testing of AC and DC Contacts

8.2.4.1 Test Conditions

The endurance test shall be made on the same contacts which were used for the overload test. The test shall consist of 6,000 operations of making and breaking the make and break amperes, respectively, specified in Tables 1-4-1 or 1-4-2 at each applicable voltage, except that contacts rated 301 volts to 600 volts shall be tested at 600 volts.

The first 12 operations shall be at maximum speed, and the contacts shall be operated by a manual control. The contacts on test do not break make current. The next 988 operations shall be at the rate of one operation per second. For these first 1,000 operations, the ON time shall be approximately equal to the OFF time.

The last 5,000 operations shall be made at the rate of six operations per minute, and the circuit controlled by the device shall be closed for approximately 1 second during each operation.

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Devices which have both normally open and normally closed contacts shall be tested in both modes, with adjacent poles at opposite polarities and in the pole configuration which represents the most severe case permitted by the instructions accompanying the device.

8.2.4.2 Test Criteria

There shall be no electrical or mechanical failure of the device, nor any undue burning, pitting or welding of the contacts.

8.2.5 Testing of AC Contacts for Abnormal Conditions of Use

AC contacts shall be capable of interrupting their rated make current or voltamperes under abnormal conditions of use. The test to verify conformance shall be made on contacts which have completed the endurance test and shall consist of making and breaking a current equal to 100 percent of the make current shown in Table 1-4-1 at 100 percent of each applicable voltage. The test shall consist of six operations at the rate of six per minute with the contacts closed for approximately 1 second during each operation. There shall be no electrical or mechanical failure of the device.

8.2.6 Test Loads for AC Contacts

The test load shall have a lagging power factor of 0.35 or less. The loads shall consist of any combination of electromagnets which results in the make and break amperes shown in Table 1-4-1 and specified power factor, except that, if loads in parallel are used, all such parallel loads shall have the same coils, the same magnets and the same air gaps. A recommended test circuit is shown in Figure 1-8-1.

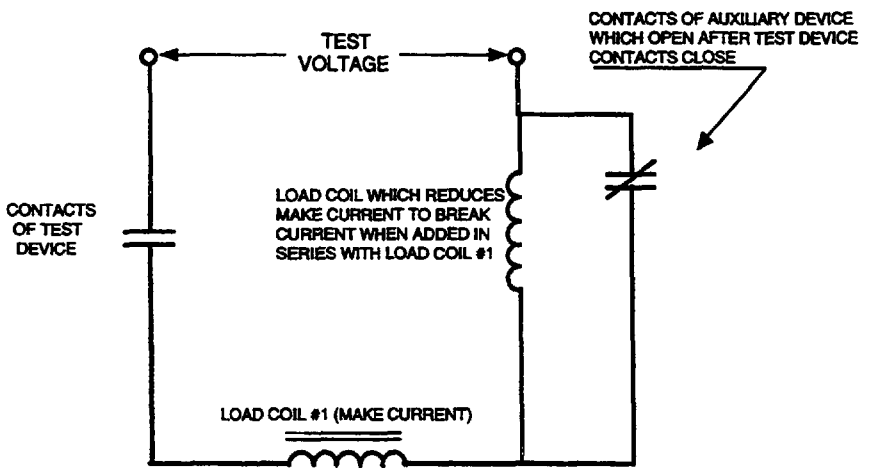


Figure 1-8-1
Recommended Test Circuit for Contacts

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8.2.7 Inductive Test Loads for DC Contacts

8.2.7.1 Construction

The following inductive test loads shall be used to approximate the loads imposed upon contacts used in DC control circuits.

For the N150 through P600 loads, the magnetic circuit shall be made up of two solid steel cores, 1.75 inches (44 mm) in diameter and 6.25 inches (159 mm) long, which are fastened by screws at each end to solid steel yokes 1 x 2-1/2 x 6 inches (25 x 63 x 152 mm) on 4 inch (102 mm) centers. See Figure 1-8-2.

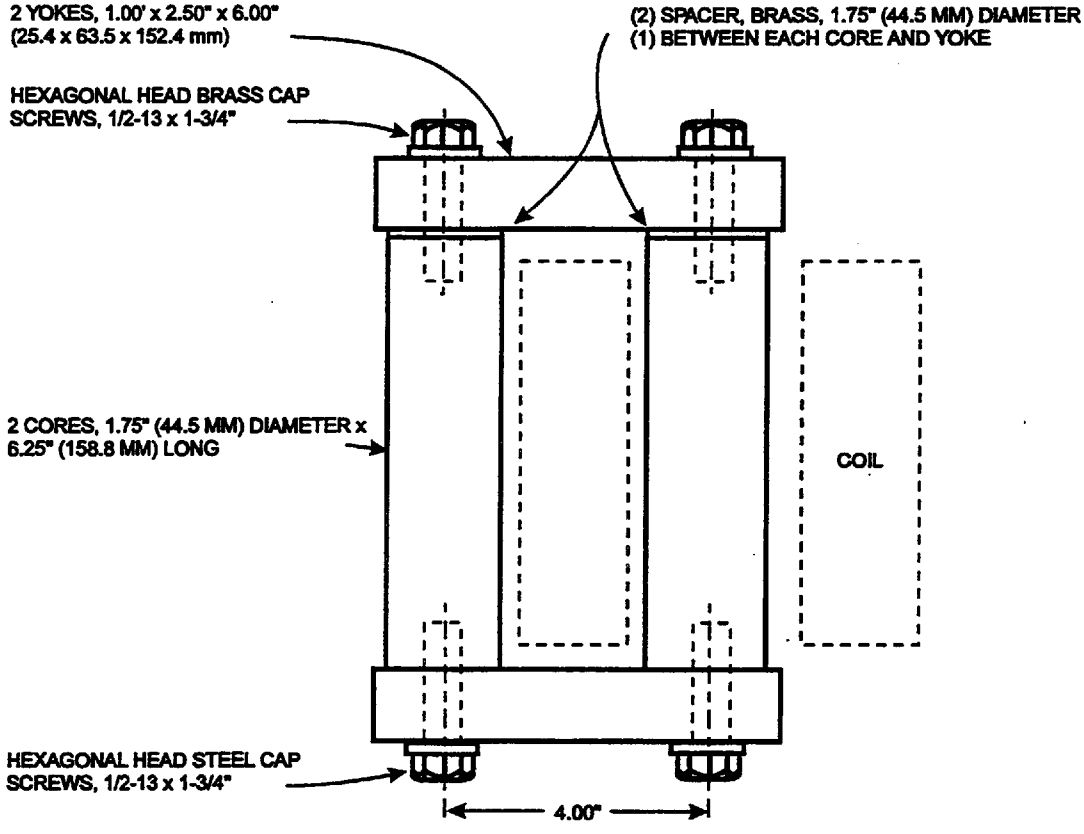


Figure 1-8-2
Construction of Load for DC Contacts N and P

For the Q150 through Q600 loads, the magnetic circuit shall be made up of two solid steel cores, 1.5 inches (38 mm) in diameter and 4.5 inches (114 mm) long, which are fastened by screws at each end to solid steel yokes 1 x 1.75 x 4.5 inches (25 x 44 x 114 mm) on 3 inch (77 mm) centers. See Figure 1-8-3.

The steel shall have a resistance of between 80 and 120 ohms per circular mil-foot (between 13 and 20 microhm-cm). (Cold-finished low-carbon steels such as AISI 1010, 1015, 1018 or 1116 meet this requirement).

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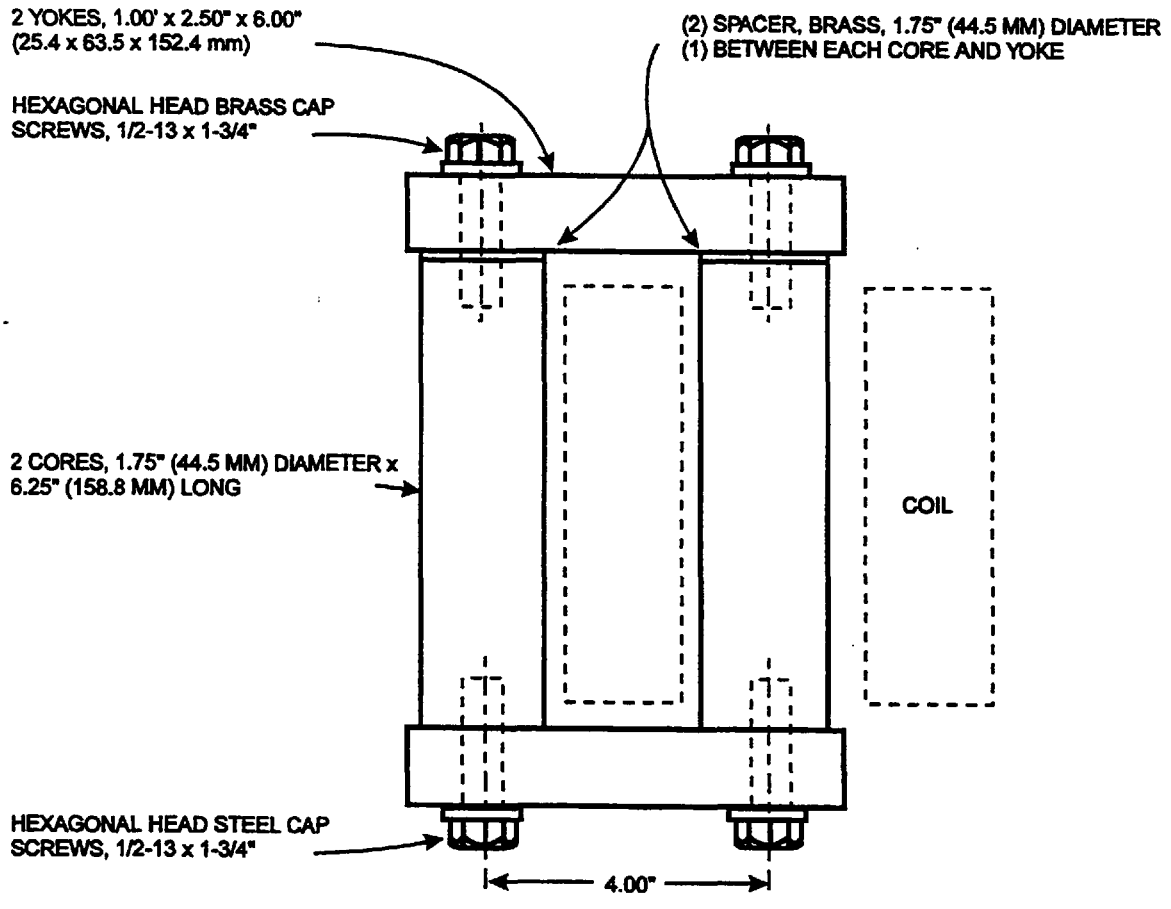


Figure 1-8-3
Construction of Load for DC Contacts Q

At one end of each core, a nonmagnetic spacer having a thickness adjustable to between 0.005 inch (0.13 mm) and 0.030 inch (0.76 mm) shall be interposed between the end of the core and the yoke. Nonmagnetic screws shall be used to hold the yoke at the end having the nonmagnetic spacer, and steel screws shall be used at the other end.

A coil having the winding characteristics shown in Table 1-8-1 shall surround one of the cores. The current in the coil, when energized at the test voltage, shall be adjusted to the value specified in the table by means of a series resistor.

The thickness of the spacer shall be adjusted so that the coil current will increase from the instant of energization to 95 percent of its full value ($T_{0.95}$) within the shaded area shown in Figure 1-8-4. If the current is above the shaded area the cross section of the yokes or cores, or both, shall be increased. Alternatively, if the current is below the shaded area, the cross section of the yokes or cores, or both, shall be reduced.

For the R150 and R300 contact ratings the load is not detailed, but it shall be an iron-cored electromagnet, in series with a resistor (if needed), to obtain the make or break current values shown in Table 1-8-1. The coil current shall increase from the instant of energization to 95 percent of its full value ($T_{0.95}$) within the shaded area shown in Figure 1-8-4.

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Table 1-8-1
DC Loads

Test Voltage, Volts	Coil Construction		Approximate Coil Resistance, Ohms	Series Resistor Limits Current to, Amperes	Voltamperes at Test Voltage	Milliseconds (± 10%)
	Number of Turns	Wire Size, AWG				
125	7000	20	74	1.1	138	300
250	14000	23	295	0.55	138	300
600	33400	27	1680	0.20	120	300

• $T_{0.95}$ = time to reach 95 percent of final current after application of test voltage to the load.

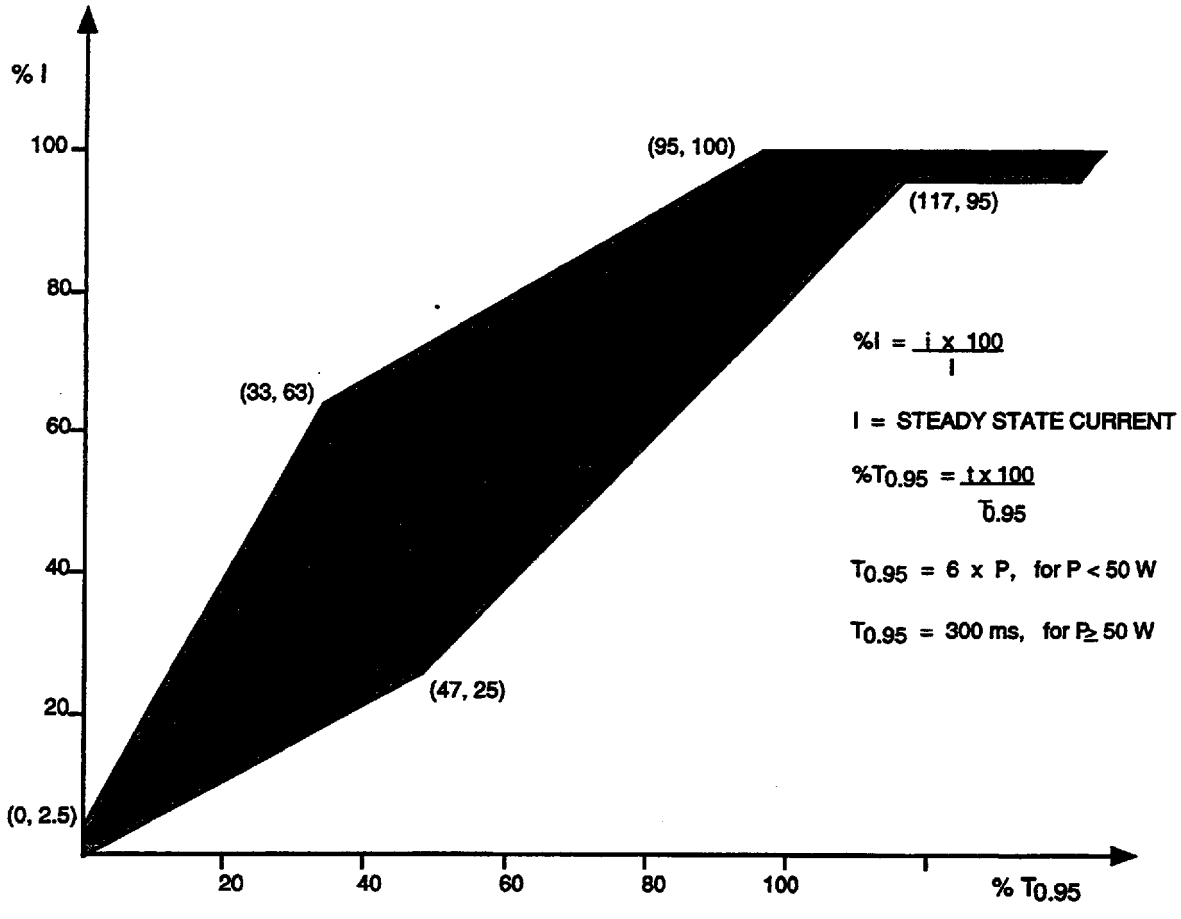


Figure 1-8-4
CURRENT/TIME LIMITS FOR DC CONTACT LOAD

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8.2.7.2 Explanation

The DC inductive loads found in control circuits are usually electromagnetically driven relays, contactors and solenoids rated 50 watts or less. The severity of these loads on the contacts of the control device is determined by the stored energy of the inductor, which is related to the average rate of rise of the current in the inductor or to the charging time of the inductor. It has been empirically determined that inductive loads up to 50 watts in size usually have a charging time ($T_{0.95}$) to 95 percent of their full current value of 6 milliseconds per watt or less.

Where the test load is intended to represent loads totalling more than 50 watts, the $T_{0.95}$ charging time of the test inductor shall be 270 to 330 milliseconds.

Test loads for coils of less than 50 watts may be designed on the basis of a 95-percent charging time ($T_{0.95}$ milliseconds) equal to six times the watts.

8.3 Requirements and tests for semiconductor switching elements

8.3.1 General

The following design (type) tests shall be used to demonstrate conformance with these standards. The device containing the switching element to be tested shall be mounted as intended to be used in service. If the device has more than one switching element, adjacent switching elements shall be wired with opposite polarity unless otherwise noted by the manufacturer.

8.3.2 Temperature Test

8.3.2.1 Test Conditions

Where tested without making or breaking current, a switching element shall be tested carrying its rated operational current. If the switching element rating is based on the use of a heat sink or mounting means, a suitable heat sink or mounting means as supplied or recommended by the manufacturer shall be used for these tests.

Switching elements designated with the prefix SA and SN shall be tested with 14 AWG copper wire, switching elements with prefix SB and SP, with 20 AWG copper wire and the balance with 22 AWG copper wire. The length of wire connected at each terminal shall be 4 feet (1.2 meters), which is 8 feet (2.4 meters) from terminal to terminal.

8.3.2.2 Test Criteria

Busses, connecting straps, terminals and insulating systems shall not exceed the allowable temperature rise specified in ICS 1, Clause 8 for these items.

8.3.3 Verification of Make and Break Capability

The tests are intended to verify that the switching element is capable of performing its intended duty according to the utilization category, rating designation and conditions of use.

8.3.3.1 Normal Conditions of Use

A switching element shall be tested in accordance with Table 1-8-2.

The first 50 operations shall be run at $U/U_e = 1.1$ with the loads set to yield the specified load currents of I/I_e where $U/U_e = 1$. This is the overload segment of the test.

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The next 6,000 operations shall be run at $U/U_e = 1$ and shall make and break the test circuit as specified in Table 1-8-2. The test shall be performed in the following sequences:

The first 1,000 operations shall be at the rate of one operation per second except the first ten operations shall be manual operations made as rapidly as possible while making sure of the actual operation of the switching element.

Where the construction of the device is such that rapid manual operation is not possible, the rate of operation shall be six operations per minute or as fast as the device will permit.

The remaining 5,000 operations shall be at the rate of six operations per minute with the switching element conducting for the specified on-time.

Table 1-8-2
Verification of Making and Breaking Capabilities of Semiconductor Switching Elements Under Normal Conditions of Use

	Make				Break							
Utilization Category	I/I_e	U/U_e*	$T_{0.95}$ ms	Power Factor (Cos θ)	I/I_e	U/U_e*	$T_{0.95}$ ms	Power Factor (Cos θ)	Test Sequence	Number of Operations	Operations per Minute	ON Time seconds†
AC-12	1	1	...	0.9	1	1	...	0.9	1	50	6	0.05
AC-13	2	1	...	0.65	1	1	...	0.65	2		‡	
AC-14	6	1	...	0.3	1	1	...	0.3				
AC-15	10	1	...	0.3	1	1	...	0.3	3		60	
DC-12	1	1	1	...	1	1	1	...				
DC-13	1	1	[6P]**	...	1	1	[6P]**	...	4		6	
DC-14	10	1	15	...	1	1	15	...				

I^e = rated operational current

U_e = rated operational voltage

$T_{0.95}$ = time to reach 95% of the steady-state curent in milliseconds

$P = U_e I_e$ = Steady-state power consumption, in watts

I = Test current, make or break

U = Test voltage, opencircuit (before make)

* The first 50 operations shall be run at $U/U_e = 1.1$, with the loads set at U_e.

** The value of "[6P] ms" results from an empirical relationship which is found to represent moderate DC magnetic loads. The maximum time constant shall not exceed 60 ms.

† The I/I_e make current for AC switching elements shall be two cycles in duration. The remainder of the ON-time shall be at the I/I_e breaj cyrrebt. The duration of the ON-time may have to be extended to provide time for switching the test circuit from make current to break current, or to permit the DC test current to reach the $T_{0.95}$ value.

‡ Rapid Manual Operations

8.3.3.2 Abnormal Conditions of Use

The test shall be made on switching elements which have completed the normal conditions test and shall consist of making and breaking the values shown in Table 1-8-3.The test shall consist of ten operations at the rate of six per minute with the switching element closed for 0.5 second during each operation.

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Table 1-8-3
Verification of Making and Breaking Capabilities of Semiconductor Switching Elements Under Abnormal Conditions of Use

	Make				Break						
Utilization Category	I/I_e	U/U_e	$T_{0.95}$ ms	Power Factor (Cos θ)	I/I_e	U/U_e	$T_{0.95}$ ms	Power Factor (Cos θ)	Number of Operations	Operations per minute	ON Time seconds
AC-12	...	...		...	...	...		...	10	6	0.05
AC-13**	10	1.1		0.65	1.1	1.1		0.65	10	6	0.05†
AC-14	6	1.1		0.3	0.6	1.1		0.3	10	6	0.05
AC-15	10	1.1		0.3	10	1.1		0.3	10	6	0.05
DC-12	...	...		...	...	...		...	10	6	0.05
DC-13**	1.1	1.1	[6P]*		1.1	1.1	[6P]*		10	6	0.05
DC-14	10	1.1	15		10	1.1	15		10	6	0.05

I_e = rated operational current

U_e = rated operational voltage

$T_{0.95}$ = time to reach 95% of the steady-state current, in milliseconds

$P = U_e I_e$ = steady-state power consumption, in watts

I = Test current, make or break

U = Test voltage, open circuit (before make)

* The value of "[6P]" milliseconds results from an empirical relationship which is found to represent moderate DC magnetic loads. The maximum time constant shall not exceed 60 ms.

** An overload protection device specified by the manufacturer should be used to protect the semiconductor or switching element during this test.

† For AC-13 switching elements, the I/I_e make current shall be one-half cycle in duration. The duration of break c urrent of the ON-time may have to be extended to provide time for switching the test circuit from make current to break current, or to permit the DC test current to reach the $T_{0.95}$ value.

8.3.3.3 Test Loads for AC Switching Elements

The loads shall consist of any combination of electromagnets or air core loads and resistors which results in a minimum two cycle make current and rated operational current shown in Table 1-4-4. If loads in parallel are used, all such parallel loads shall be identical. An example of a test circuit is shown in Figure 1-8-5. The test load power factor shall be as specified in Tables 1-8-2 and 1-8-3.

8.3.3.4 Test Loads for DC Switching Elements

The test load shall have a resistance to yield the final currents described in Table 1-4-4 and the rise times described in Tables 1-8-2 and 1-8-3. If loads in parallel are used, all such parallel loads shall be identical.

8.3.3.5 Test Criteria

During the test there shall be no electrical or mechanical failures. After the test, the switching element shall meet the dielectric requirements of ICS 1, Clause 8.

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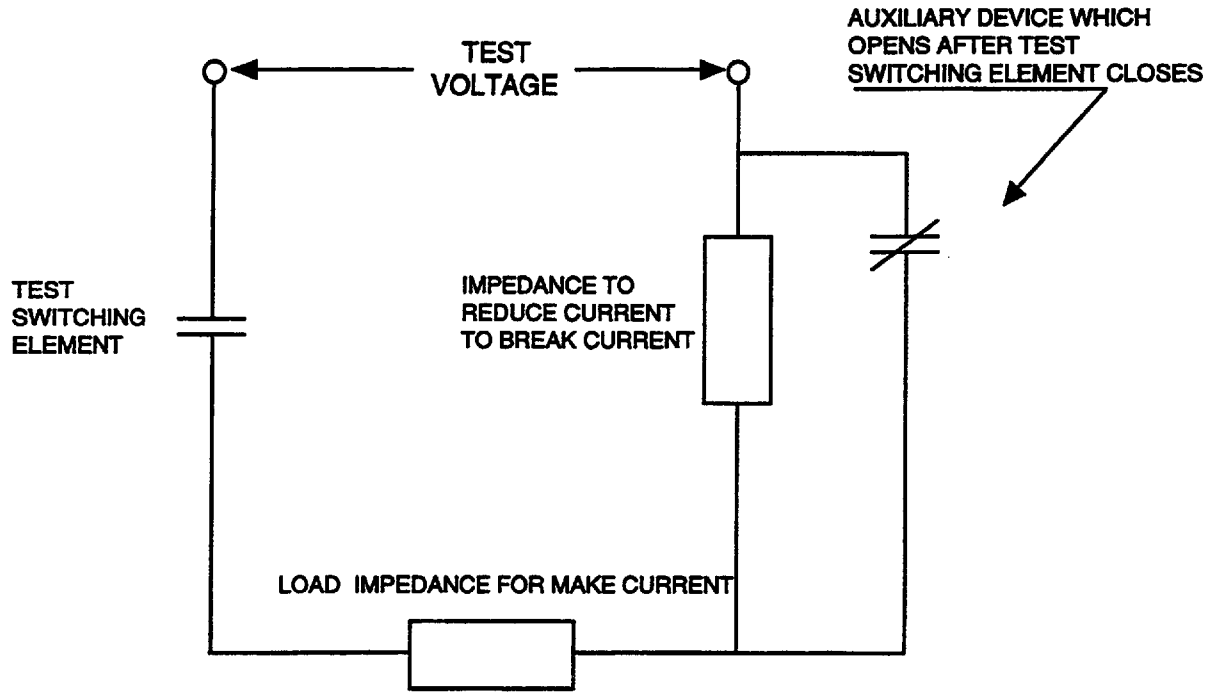


Figure 1-8-5
Recommended Test Circuit for AC Switching Elements

9 APPLICATION

9.1 Contact Life

The life of mechanical control-circuit contacts depends upon the magnitude and characteristics of the electrical load, inductance, duty cycle, mechanical properties of the device in which they are used, voltage fluctuations, environment, etc. When control circuit devices are operated at maximum rated load, the life of the contacts is usually less than that of the remainder of the device. If the application requires a large number of operations during the life of the contacts, the contacts must be applied at values much less than their maximum make and break ratings. See the parts of this publication relating to the specific control circuit devices.

9.2 Polarity

Polarity, as applied to contacts and terminals (see Figure 1-9-1) is a term which is used to describe the relationship between the load and line connections to a multicircuit switch. When two or more sets of contacts are so connected in a circuit that a short circuit will not occur when all of the terminals of these contacts are made electrically common, these contacts are said to be connected to the same polarity.

When a short circuit will occur, these contacts are said to be of opposite polarity.

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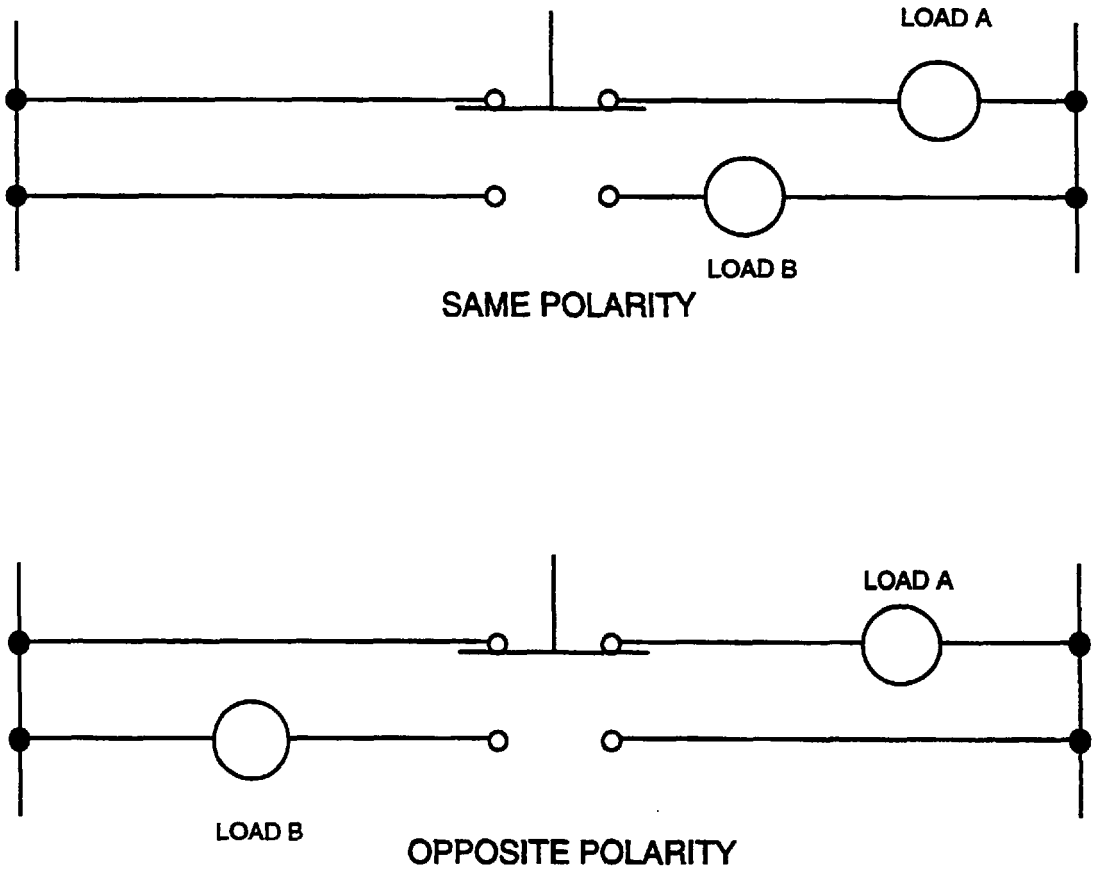


Figure 1-9-1
Polarity

9.3 Polarity Marking

When the contacts of a control circuit device are not suitable for use on opposite polarity, the manufacturer shall designate these contacts as being suitable for use only on the same polarity.

9.4 Component Applications

Reed switches may be used as contact assemblies in relays, limit switches, pushbuttons, logic elements, etc.

9.5 Control-Circuit-Type Switches

Control-circuit-type dry reed switches have the advantage of providing relatively high speed operation and contact reliability even when exposed to environmental contamination.

9.6 Logic-Type Switches

Logic-type dry reed switches provide contact reliability at low values of voltage and current, and relatively high speed operation, even where exposed to environmental contamination. The contacts of

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coil-operated dry reed switches having a fanout rating may be applied in logic circuits consisting of similar coil-operated dry reed switches. Logic-type dry reed switches used in other applications should be tested to verify their suitability, particularly when the load is nonresistive and arc suppression is required. Logic-type dry reed switches are often used as the interface device between solid-state and nonsolid-state devices.

9.7 Arc Suppression

Contacts which operate inductive loads may require protection by arc suppression networks. These may be connected across either the load or the contacts. The network may consist of a resistor in series with either a capacitor or diode. (For alternating current, the diode should be a thyrector.)

The effectiveness of the suppressor network should be checked by an oscilloscope to assure that transient voltages do not exceed the voltage ratings of the contacts or, alternatively, the relay manufacturer should be consulted for recommendation.

9.8 Voltage Variation Requirement for Static Switching Control Elements

The control system shall operate on a supply voltage from minus 10 percent to plus 10 percent of the rated control system voltage.

9.9 Application Considerations

Refer to ICS 1.1, with particular emphasis upon personnel safety for safety requirements when applying solid state devices.

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Part 2
INDUSTRIAL CONTROL RELAYS

1 GENERAL

1.1 Scope

The standards in this part apply to 50 and 60 hertz, AC and DC magnetic control relays and time-delay (timing) relays principally used in control circuits of industrial control apparatus.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 5, part 1 apply to this part unless otherwise stated.

2 DEFINITIONS

For the purposes of this part the following definitions apply.

alternating-current (AC) relay: A relay which is designed to be actuated from an AC source.

clock timer: A type of repeat cycle timer whose timing intervals are based on time of day.

convertible contact construction: A contact construction which can be changed from normally open to normally closed and vice versa in the field.

direct-current (DC) relay: A relay which is designed to be actuated from a DC source.

fixed contact construction: A contact construction which cannot be changed from normally open to normally closed or vice versa in the field.

instantaneous switching element (contact or semiconductor): The contact or semiconductor switching elements which operate at the time the relay is energized and deenergized. They are independent of the timed switching elements.

interval timing relay: A type of timing relay which changes the state of its timed contact(s) for predetermined time(s). An interval timer may have more than one predetermined time interval.

maintained interval timing relay: A type of interval timing relay that requires the initiating signal be maintained for a period not less than the preset timing interval of the timed contacts.

momentary interval timing relay: A type of interval timing relay in which the timing interval of the timed contacts is independent of the duration of the initiating signal.

pneumatic time-delay relay: A timing relay which has its timing period controlled by the rate at which air moves through an adjustable or fixed orifice.

repeat accuracy deviation: A measure of the maximum deviation in the time delay that will be experienced in successive operations at any particular time setting of the relay and for any particular operating voltage, frequency or current. Repeat accuracy deviation is determined as one half of the total timing variation at any particular time setting, divided by the average of the maximum and minimum observed time periods for any 100 consecutive operations, expressed in terms of plus or minus percentage.

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Repeat accuracy is obtained from the following formula:

$$A_R = \pm 100 \frac{{}^1/_2(T_1 - T_2)}{{}^1/_2(T_1 + T_2)} = \pm 100 \frac{(T_1 - T_2)}{(T_1 + T_2)}$$

Where:

A_R = Percent repeat accuracy deviation at any particular time setting

T_1 = Maximum observed time*

T_2 = Minimum observed time*

* To be obtained over 100 consecutive operations; the time allowed for resetting shall not be less than the reset time.

repeat cycle timer: A type of interval timing relay that repeats its timing interval(s) periodically for as long as the timer remains energized.

solid-state time-delay relay: A timing relay which has its timing period controlled by a circuit using semiconductors. A solid-state time-delay relay may have a semiconductor or a contact switching element.

time-delay relay; timing relay: A relay which has an assured time interval between energization and the action of the switching element, or between deenergization and the action of the switching element. The former are called "Time Delay after Energization (TDE)" or "On-Delay" relays, and the latter are called "Time Delay after Deenergization (TDD)" or "Off-Delay" relays.

timed switching elements (contact or semiconductor): Those contact or semiconductor switching elements of a timing relay which operate immediately after the time delay.

universal contact construction: A form of fixed contact construction in which the pole has both normally open and normally closed contacts but in which only one or the other mode may be used.

3 CLASSIFICATION

3.1 Contact Forms

Fixed and convertible contact constructions may be used for all of the contact forms described in Clause 2 of Part 1.

3.2 Control Relay and Time-Delay Relay Class Designations

The classes of relays shall be designated in terms of their contact ratings, by means of the letters and numerals given in Clause 4 of Part 1, in the following manner:

a. A letter (not to be confused with the form letter such as "form A Contact") which indicates the maximum continuous thermal test current as shown in Table 2-3-1

b. A numeral following the letter which indicates the maximum voltage rating of 600, 300 or 150 volts

Example-A relay designated A600 is a relay which has A600 contacts, is suitable for use at all AC voltages through 600 volts, is built to the 600-volt spacing requirements given for Group A controls in ICS 1, Table 7-1, and has a continuous thermal test current rating of 10 amperes and make and break ratings in accordance with Table 1-4-1.

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Table 2-3-1
Contact Class Designations

Letter Designation		Continuous Thermal Test Current, Amperes
Alternating Current	Direct Current	
A	N	10.0
B	P	5.0
C	Q	2.5
D	R	1.0
E		0.5

4 CHARACTERISTICS AND RATINGS

4.1 Relay Coils

Control relays and magnetically-operated time-delay relays shall be equipped with coils having the ratings shown in Table 2-4-1. The coil shall have only one rating for any one frequency. See ICS 1.

Table 2-4-1
Ratings of Coils for Control Relays and Time-Delay Relays

AC Volts		DC Volts
50 Hertz	60 Hertz	
110	6	6
115	12	12
127	24	24
220	48	36
240	115 or 120*	48
380	200 or 208*	72
415	230 or 240*	115 or 120*
	265 or 277*	230 or 240*
	460 or 480*	550 or 600*
	575 or 600*	

* A coil may be rated for both voltages, e.g., 115–120

4.2 Switching Elements

4.2.1 Control and Time-Delay Relay Ratings

The contact ratings of control and time-delay relays shall be in accordance with Clause 4 of Part 1. See Clause 9 of this Part for application guidelines.

4.2.2 Semiconductor Switching Element Ratings

The ratings of time-delay relays having semiconductor switching elements for use in control circuits shall be in accordance with Clause 4 of Part 1 for the utilization category specified.

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5 PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION

See NEMA Standards Publication ICS 1.3 for preventative maintenance instructions.

6 SERVICE AND STORAGE CONDITIONS

See ICS 1, Clause 6 for normal service and storage conditions.

7 CONSTRUCTION

No construction requirements are included in this Part.

8 PERFORMANCE REQUIREMENTS AND TESTS

8.1 Switching Element Performance Requirements

8.1.1 Mechanical Contact Performance

The contacts of a control relay or time-delay relay shall be capable of passing the overload, endurance and abnormal conditions of use tests described in Clause 8 of Part 1.

8.1.2 Semiconductor Switching Element Performance Requirements

Semiconductor switching elements, where used as output for time-delay relays, shall meet the test and performance requirements of Clause 8 of Part 1 corresponding to their rating designation for the utilization category specified.

8.1.3 Temperature Rise of Contacts

The contacts of a control relay or time-delay relay, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rises given in ICS 1, Clause 8. The temperature rise test on contacts shall be made on unused contacts carrying, but not making or breaking, current.

8.2 Coil Performance Requirements

8.2.1 Range of Coil Operating Voltage

AC magnetically-operated control relays and time-delay relays shall withstand 110 percent of the rated voltage of the operating coil continuously without injury to the coil and shall close successfully at 85 percent of the rated coil voltage after being preheated to constant temperature at the rated coil voltage. If the rating of the operating coil is given as a voltage range, the relay shall withstand 110 percent of the higher voltage continuously without injury to the coil and shall close successfully at 85 percent of the lower voltage after being preheated to constant temperature at the lower voltage rating. DC magnetically operated control relays and time-delay relays shall withstand 110 percent of the rated voltage of the operating coil continuously without injury to the coil and shall close successfully at 80 percent of the rated coil voltage after being preheated to constant temperature at the rated coil voltage.

See ICS 1, Clause 8 for test procedure.

8.2.2 Coil Temperature Rise

The coil temperature rise of a control relay or time-delay relay, when operating at rated voltage, shall not exceed the limits given in ICS 1, Clause 8.

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8.3 Terminal Temperature Rise

The field wiring terminals of control relays and time-delay relays, when operating at rated voltage and carrying continuous thermal test current, shall not exceed the temperature rise given in NEMA Standards Publication No. ICS 1, Clause 8 when wired as shown in Table 2-8-1.

The terminals of all poles of the same mode shall be wired in series with 4 feet (1.2 meters) of wire per terminal (8 feet or 2.4 meters from terminal to terminal).

Table 2-8-1
Conductor Sizes for Testing

Continuous Test Current Rating, Amperes	Copper Wire Size, AWG
5.1–10	14
2.6–5.0	20
2.5 and less	22

8.4 Dielectric Test

8.4.1 Control and Time-Delay Relays with Contacts

A control relay or a time-delay relay with contacts shall be capable of withstanding the power frequency dielectric test described in ICS 1, Clause 8 when mounted as it is intended to be used in service.

8.4.2 Time-Delay Relays with Semiconductor Switching Elements

A time-delay relay with a semiconductor switching element shall be capable of withstanding the power frequency dielectric test described in ICS 1, Clause 8 except that the test between the time delay initiating circuit and the output circuit shall be omitted.

9 APPLICATION

9.1 Application Guide for Control Relays and Time-Delay Relays with Mechanical Contact Switching Element

The make and break ratings and test values shown in Tables 1-4-1 and 1-4-2 of Part 1 shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, the break current of the load shall be considered to be 50 percent of the make current of the load. The load limitations given in the following paragraph include provision for this situation.

When control relays or timing-relays are used in a typical automatically operated sequencing system, it is recommended that the load be less than 25 percent of the maximum make and break ratings given in Tables 1-4-1 and 1-4-2 of Part 1.

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in

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this NEMA Standards Publication. Therefore, manufacturer's recommendations should be obtained regarding specific applications.

9.2 Application Guide for Time-Delay Relays Having Semiconductor Switching Elements

The utilization categories given in Clause 4 of Part 1 are considered standard.

Applications not covered by standard utilization categories should be based on agreement between the manufacturer and user.

Consideration should be given to the degree of isolation necessary between the time-delay initiating circuit and the output circuit when applying semiconductor time-delay relays.

9.3 Overlapping Contacts

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a timing relay may or may not be conducting current simultaneously during operation. If such overlap or nonoverlap is essential, the manufacturer should be consulted.

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Part 3
INDUSTRIAL CONTROL INPUT DEVICES ACTUATED BY FORCE, TEMPERATURE OR PRESSURE

1 GENERAL

1.1 Scope

The standards in this part apply to limit (position) switches, pressure switches, temperature switches and liquid-level switches that are actuated by force, pressure or temperature and used as inputs to control circuits of industrial control apparatus. This part also applies to auxiliary contacts of controllers and disconnect devices used in the control circuits of industrial control apparatus.

The switches and auxiliary contacts are rated for AC and DC control circuit applications of 600 volts or less.

See Part 5 for standards that apply to push buttons and selector switches.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and ICS 5, Part 1 apply to this part unless otherwise stated.

2 DEFINITIONS

For the purposes of this part, the following definitions apply.

The definitions in this clause are grouped according to switch category and listed alphabetically in each category.

2.1 Definitions of Switch Types

basic switch: A snap-acting switch of either the open type, skeleton type, or the type encased within an envelope. A basic switch is normally used within a protective enclosure or is used as a component.

float switch: A liquid-level switch which is operated by a buoyant constituent part.

foot switch: A switch which is suitable for operation by an operator's foot.

lever-operated limit switch: A limit switch in which the contact mechanism is controlled by an actuator lever attached to a rotatable shaft that is an integral part of the limit switch.

limit switch; position switch: A switch that is operated by some part or motion of a power-driven machine or equipment to alter the electrical circuit associated with the machine or equipment.

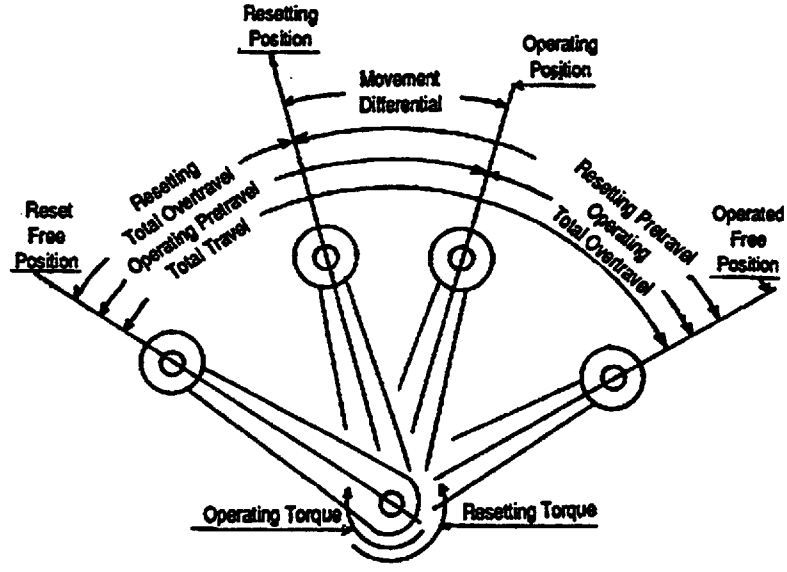
liquid-level switch: A switch which is responsive to the level of a liquid.

The design of a liquid-level switch may be based on such principles as buoyancy, liquid weight, optics, capacitance, sound, etc.

maintained contact limit switch; reset switch: A switch that remains in a given condition until actuated to another condition, which is also maintained until further actuation.

See 2.2.3 and Figures 3-2-1 and 3-2-2.

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NOTE—All positions, travels and torques can be reversed.

Figure 3-2-1
Maintained Contact Lever-Operated Limit Switch

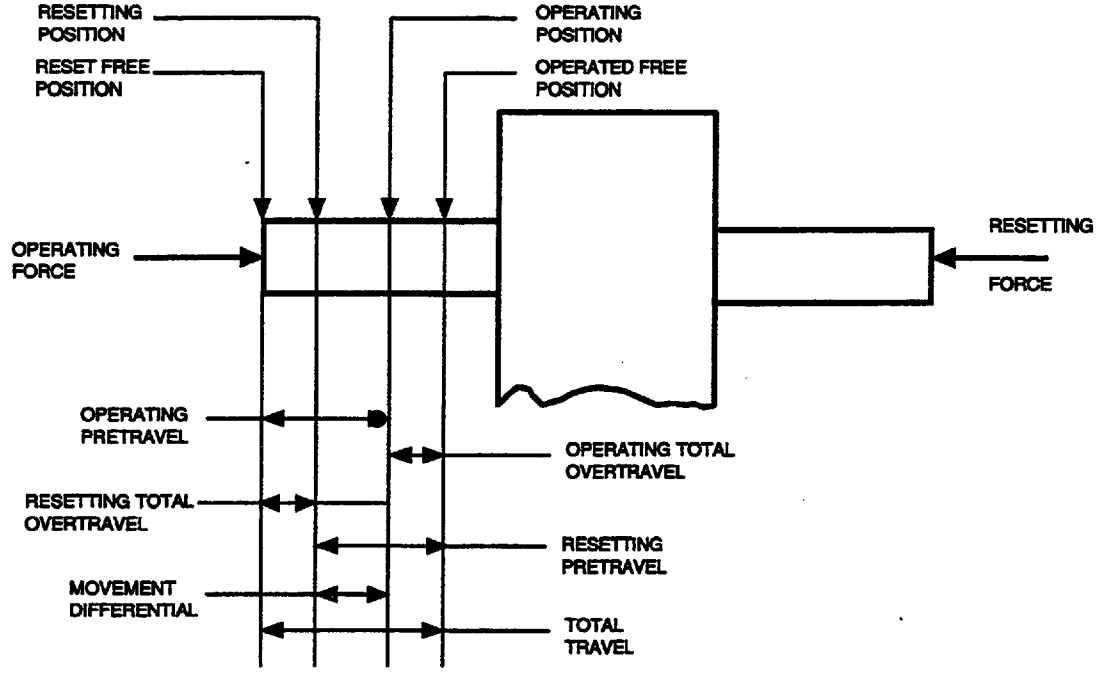
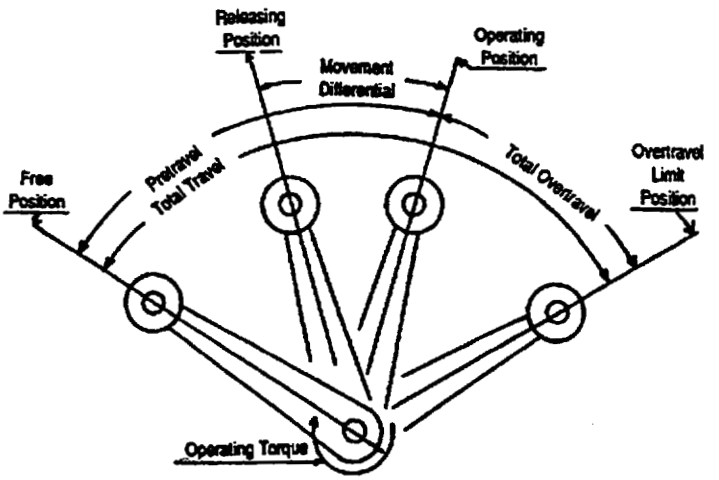


Figure 3-2-2
Maintained Contact Plunger-Operated Limit Switch

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momentary contact limit switch: A limit switch that returns from the operated condition to its normal circuit condition when the actuating force is removed.

See 2.2.2 and Figures 3-2-3 and 3-2-4.



NOTE—Free position can be on the right with all positions, travels and torques reversed.

Figure 3-2-3
Momentary Contact Lever-Operated Limit Switch

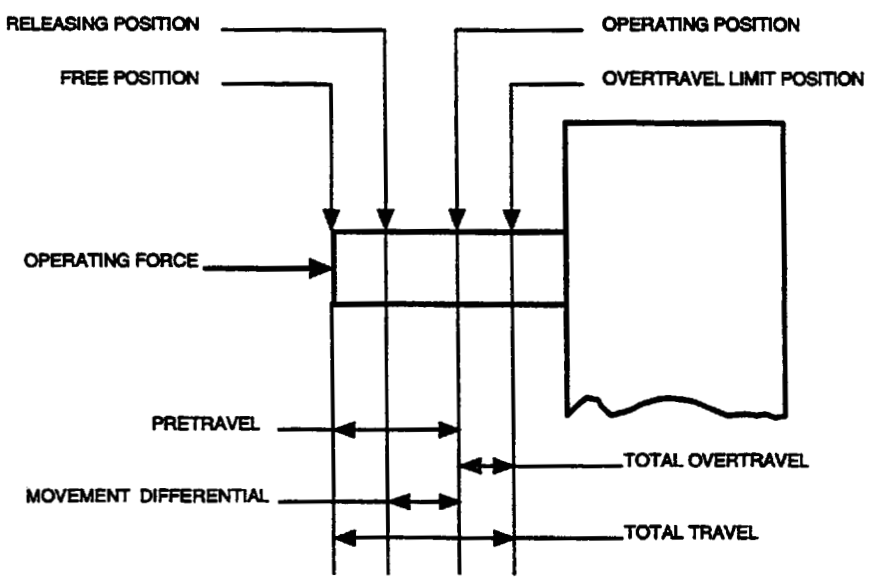


Figure 3-2-4
Momentary Contact Lever-Operated Limit Switch

plunger-operated limit switch: A limit switch in which the contact mechanism is operated by a plunger-type device.

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power-circuit limit switch: A limit switch the contacts of which are in the power circuit.

precision snap-acting switch: A mechanically operated electric switch having predetermined and accurately controlled characteristics, and having contacts other than the blade and jaw, or mercury type, where the maximum spearation between any butting contacts is 1/8 inch (3.2 millimeters). A precision snap-acting switch consists of a basic switch used alone, a basic switch used with an actuator (s), or a basic switch used with an actuator (s) and an enclosure.

pressure limit control: A pressure switch set beyond the process operating pressure to limit the operation of the controlled equipment under abnormal conditions.

pressure switch: A switch that is operated by a constituent part and is responsive to fluid (gas or liquid) pressure.

A pressure switch that operates primarily at pressure less than atmospheric is called a vacuum switch.

proportional temperature controller: A controller that is responsive to temperature and which has a continuous proportional relationship between its output and its input within its operating temperature range.

rotating cam limit switch: A limit switch in which the contact mechanism is operated by internal camming on a rotatable shaft that is an integral part of the limit switch and capable of being rotated through 360 degrees continuously.

snap-acting switch: A switch in which there is a rapid motion of the contacts from one position to another position, or their return. This action is relatively independent of the rate of travel of the actuator.

temperature limit control: A temperature switch set beyond the process operating temperature to limit the operation of the controlled equipment under abnormal conditions.

temperature switch: A two-state (ON-OFF) controller which is responsive to the temperature of a sensed medium.

2.2 Definitions for Limit Switches

2.2.1 General Definitions Applying to Limit Switches

actuating point: The point on an actuator at which operating force is applied.

actuator: The mechanism of the switch or enclosure which, when moved as intended, will operate the contacts.

auxiliary actuator: A mechanism which may be attached to a switch to modify its characteristics.

break distance: The effective open-gap distance between the stationary and movable contacts.

contact force: The force exerted by the moving contact on a stationary contact.

limit switch enclosure: A supplemental protection means for the basic switch but which does not necessarily form an integral part thereof.

operated contact position: The position to which the contacts move when the actuator is traveled to or beyond the actuator operating position.

operating force: The straight-line force in the designated direction applied to the actuator to cause the switch contacts to snap to the operated contact position.

operating position: The position of the actuator at which the contacts snap to the operated contact position.

operating torque: The minimum torque applied to the actuator to cause the moving contact to snap to the operated contact position.

overtravel: The movement of the actuator beyond the operating position.

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overtravel limit position: That position of the actuator beyond which further overtravel would cause damage to the switch or actuator.

repeat accuracy deviation: One half of the angular or linear variation in the travel of the actuator to reach an operating or resetting position divided by the average of the maximum and minimum observed travels for any 100 consecutive operations, expressed in terms of plus or minus percentage.

Repeat accuracy deviation is obtained from the following formula:

$$A_R = \pm 100 \frac{{}^1/_2(X_1 - X_2)}{{}^1/_2(X_1 + X_2)} = \pm 100 \frac{(X_1 - X_2)}{(X_1 + X_2)}$$

Where:

A_R = Percent repeat accuracy deviation

X_1 = Maximum observed travel*

X_2 = Minimum observed travel*

To be obtained over 100 consecutive operations.

repeatability: The ability to consistently maintain the original operating characteristics.

total travel: The sum of the pretravel and total overtravel.

2.2.2 Definitions Applying to Momentary Contact Limit Switch

(See Figures 3-2-3 and 3-2-4 for illustrations)

force differential: The difference between operating force and the releasing force.

free position: The initial position of the actuator where there is no external force (other than gravity) applied on the actuator and the switch is in the specified position.

movement differential: The distance or angle from the operating position to the releasing position.

normal contact position: That position of the contacts which exists when no operating force is applied.

pretravel: The distance or angle through which the actuator moves from the actuator free position to the actuator operating position.

releasing force: The value to which the force on the actuator must be reduced to allow the contacts to snap from the operated contact position to the normal contact position.

releasing position: That position of the actuator at which the contacts snap from the operated contact position to the normal contact position.

releasing torque: The value to which the torque on the actuator must be reduced to allow the contacts to snap from the operated contact position to the normal contact position.

torque differential: The difference between the operating torque and the releasing torque.

total overtravel: The distance or angle through which the actuator moves when traveling from the actuator operating position to the overtravel limit position.

2.2.3 Definitions Applying to Maintained Contact Limit Switches

(See Figures 3-2-1 and 3-2-2 for illustrations.)

movement differential: The distance or angle from the operating position to the resetting position.

operated free position: The position of the actuator where there is no external force (other than gravity) applied on the actuator and the switch is in the operated contact position.

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operating pretravel: The distance or angle through which the actuator moves from the reset free position to the operating position.

operating total overtravel: The distance or angle through which the actuator moves when traveling from the operating position to the operated free position.

reset contact position: The position to which the contacts snap when the actuator is traveled to or beyond the resetting position.

reset free position: The position of the actuator where there is no external force (other than gravity) applied on the actuator and the switch is in the reset contact position.

resetting force: The force which must be applied to the resetting mechanism to cause the moving contact to snap from one position to another.

resetting position: The position of the actuator at which the moving contact snaps from the operated contact position to the reset contact position.

resetting pretravel: The distance or angle through which the actuator moves from the operated free position to the resetting position.

resetting torque: The minimum torque that is applied to the resetting mechanism to cause the moving contact to snap from one position to another.

resetting total overtravel: The distance or angle through which the actuator moves when traveling from the resetting position to the reset free position.

2.3 Definitions Applying to Pressure Switches

allowable pressure limits: The maximum and minimum pressures, stated by the manufacturer, to which a pressure switch may be exposed for brief or extended periods without altering the performance characteristics of the switch.

Maximum allowable pressure is also referred to as overrange and includes surge pressures.

cut-in pressure: That pressure at which the switch is actuated to energize the load.

The cut-in pressure may be the trip or reset point.

cut-out pressure: That pressure at which the switch is actuated to deenergize the load.

The cut-out pressure may be the trip or reset point.

drift: An inherent change in operating value for a given setting over a specified number of operations and specified environmental conditions.

maximum static pressure: The continuous pressure which the pressure containing envelope of a pressure switch sustains without rupture.

Maximum static pressure is sometimes called rated static pressure.

operating differential pressure: The difference between cut-in pressure and cut-out pressure.

Operating differential pressure is also called dead band or hysteresis.

operating pressure range: The range between the maximum and minimum pressure settings at which a pressure switch will operate and continue to operate within the manufacturer's specifications.

proof pressure: The nondestructive static test pressure, in excess of the maximum allowable pressure, which causes no permanent deformation or malfunction.

pulsation snubber: A device used with pressure switches to reduce the effect of pressure surges within the pressure system on the pressure responsive element of the switch.

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2.4 Definitions Applying to Temperature Switches

allowable temperature limits: The maximum and minimum temperatures that a temperature switch may be exposed to without altering its performance characteristics.

cut-in temperature: The temperature of the sensed medium at which a temperature switch is actuated to energize the load.

The cut-in temperature may be the trip or reset point.

cut-out temperature: The temperature of the sensed medium at which a temperature switch is actuated to deenergize the load.

The cut-out temperature may be the trip or reset point.

operating temperature differential: The difference between the cut-in and cut-out temperatures.

Operating temperature differential is also called dead band or hysteresis.

operating temperature range: The range between the maximum and minimum temperature settings at which a temperature switch will continue to operate within the manufacturer's specifications.

remote temperature sensing: That construction and installation of a temperature switch in which the sensing unit and the switch mechanism are thermally isolated so that the temperature of the sensed medium does not affect the performance of the switch mechanism.

3 CLASSIFICATION

No classifications are included in this part.

4 CHARACTERISTICS AND RATINGS

4.1 Electrical Switching Element or Output Ratings

4.1.1 Contact Ratings

The contact ratings of these switches where used in control circuits shall be in accordance with Clause 4 of Part 1. See Clause 9 of Part 1 for application guidelines.

4.1.1.1 Standard-Duty Rating

Devices rated standard duty shall have contact rating designations of B150, B300, B600, P150, P300 or P600 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.

4.1.1.2 Heavy-Duty Rating

Devices rated heavy duty shall have contact rating designations of A150, A300, A600, N150, N300 or N600 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.

4.1.1.3 Temperature Switches and Proportional Temperature Controllers Used to Control Noninductive Loads

Ratings of temperature switches and proportional temperature controllers used to control noninductive loads shall be in terms of rated operational current or voltamperes, or both, or watts for one or more utilization voltages.

4.1.2 Semiconductor Switching Element Ratings

4.1.2.1 The ratings of switches having semiconductor switching elements for use in control circuits shall be in accordance with Clause 4 of Part 1 for the utilization category specified.

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4.1.2.2 Standard utilization categories are given in Table 1-4-3.

Applications not covered by the utilization categories in Clause 4 of Part 1 should be based on agreement between the manufacturer and the user.

4.2 Pressure Ratings

4.2.1 Pressure Switches

A pressure switch shall have a specified operating pressure range and operating differential, allowable pressure limits and a maximum static pressure. The maximum allowable pressure shall be less than the proof pressure and greater than the maximum of the operating range. All pressure values shall be expressed in terms of gauge pressure unless otherwise stated.

Unless a pressure switch is designed for operation at less than atmospheric pressure, a minimum pressure of zero is not recommended.

4.2.2 Pressure Limit Control

A pressure limit control shall have a specified cut-in or cut-out pressure, specified limits of drift, allowable pressure limits and a maximum static pressure.

4.3 Temperature Ratings

4.3.1 Temperature Switches

A temperature switch shall have a specified operating range, operating differential and allowable temperature limits.

4.3.2 Proportional Temperature Controllers

A proportional temperature controller shall have a specified operating range, a specified relation between input and output, and allowable temperature limits.

4.3.3 Temperature Limit Controls

A temperature limit control shall have a specified cut-in or cut-out temperature, specified limits of drift and allowable temperature limits.

4.3.4 Allowable Temperature Limits

The allowable temperature limits of a temperature controller shall exceed the operating temperature range.

4.3.5 Temperature Rating of Conductors

Conductors which are exposed to the sensed medium, when connected to temperature switches or proportional temperature controllers, should have a maximum operating temperature rating not less than the total temperature attained by the conductor.

5 PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION

5.1 Preventative Maintenance

A preventative maintenance program and schedule should be established to meet the needs of each particular installation to assure minimum down time. The program should include, for example, tightening

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connections, inspecting for evidence of overheating, removing dust and dirt, and replacing contacts or contact blocks in accordance with the manufacturer's recommendations.

See NEMA Standards Publication ICS 1.3 for preventative maintenance instructions.

5.2 Specific Maintenance Instructions for Float Switches

Inspect float mechanism for loss of buoyancy.

6 SERVICE AND INSTALLATION CONDITIONS

6.1 Pressure Switch Service Conditions

6.1.1 Chemical

Pressure switches should not be applied with fluids which will corrode or react chemically with the material used for the pressure containing envelope. Permissible ambient temperatures below 0°C are based on the absence of freezing moisture in the presence of moving parts.

6.1.2 Surges

A pressure switch should not be applied where its pressure containing envelope is subjected to a surge which is greater than its maximum allowable pressure. A pressure switch which is used in a system pressurized by a reciprocating pump should be protected from surges by a pulsation snubber.

6.2 Temperature Switch Service Conditions

Temperature switches and proportional temperature controllers should not be exposed to or applied at temperatures beyond the manufacturer's allowable temperature limits. Allowable temperatures below 0°C are based on the absence of freezing moisture in the presence of moving parts. Temperature controllers should not be applied with fluids which will corrode or act chemically with their sensing elements. Wells are usually available to provide protection.

6.3 Liquid Level Switch Service Conditions

Parts of liquid level switches should not be placed in contact with liquids which will corrode or react chemically with such parts. Permissible ambient temperatures below 0°C are based on the absence of freezing moisture in the presence of moving parts.

7 CONSTRUCTION

7.1 Materials for Temperature Switch Actuators

Temperature switches and proportional temperature controllers by their nature may be subjected to ambient temperature operating conditions above or below those given in ICS 1 and, therefore, should incorporate materials suitable to the application.

7.2 Maintained-Contact Limit Switches

Maintained-contact limit switches shall be manufactured or adjusted so that the contacts will not operate before the limit switch actuator has reached a point of travel at which it will continue to its operated free position without continuing external applied force.

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8 PERFORMANCE REQUIREMENTS AND TESTS

8.1 Contact Performance

8.1.1 Control Circuit Switches

The contacts of control-circuit switches when new, shall:

a. Not exceed the temperature rise given in NEMA Standards Publication No. ICS 1 when carrying continuous thermal test current.

b. Be capable of passing the overload, endurance and emergency condition tests described in Part 1.

8.1.2 Motor Control Switches

The make and break design test for switches which are rated for alternating-current motor applications shall consist of making 6 times rated full load motor current at 40 to 50 percent power factor and breaking 1.5 times full load motor current at 75 to 80 percent power factor for 50 operations in a single continuous test without intervening maintenance or servicing at a rate of six operations per minute with a minumum "ON" time of 1 second per operation. The test shall be made at rated voltage.

If the switch is provided with an overload relay, an adjusting knob, or some similar means of causing the switch to open the locked rotor current of the motor, the break current shall be 6 times rated full load current.

8.2 Semiconductor Switching Element Performance

Semiconductor switching elements shall meet the test and performance requirements of Part 1 corresponding to their rating designation for the utilization category specified.

8.3 Temperature Rise of Terminals

The field wiring terminals of a control circuit switch carrying continuous thermal test current shall not exceed the temperature rise given in ICS 1, Clause when wired according to Table 3-8-1.

For the purrposes of this test, the field wiring terminals of temperature switches, shall be wired with wire sized appropriately for the switch rating (see Table 3-8-1). The terminals of all poles of the same mode shall be wired in series with 4 feet (1.2 meters) of wire between terminals.

See Part 1 for devices rated for control circuit applications.

For temperature switches and proportional temperature controllers the temperature rise performance requirement is with the sensing element exposed to maximum allowable temperature.

Table 3-8-1
Conductors for Testing

Continuous Thermal Test Current, Amperes	Size of Copper Wire, AWG
5.1–10	14
2.6–5.0	20
2.5 and less	22

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8.4 Dielectric Test

Control-circuit switches shall be capable of withstanding the power frequency design dielectric test described in NEMA Standards Publication No. ICS 1, Clause 8 when mounted as they are intended to be used in service.

8.5 Other Requirements

8.5.1 Actuators of Pressure Switches

The parts of a pressure switch shall meet the strength requirements of Underwriters Laboratories Publications UL 353, 508, 698, or 873, as applicable.

8.5.2 Pressure Limit Controls

A pressure limit control shall be evaluated in accordance with Underwriters Laboratories Publication UL 353 or 873, as applicable.

8.5.3 Temperature Limit Control

A temperature limit control shall be evaluated in accordance with Underwriters Laboratories Publication UL 353 or 873, as applicable.

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9 APPLICATION

9.1 General Application Considerations

9.1.1 Relating Load To Rating

9.1.1.1 Mechanical Switching Elements

The make and break ratings and test values shown in Table 1-4-1 for AC and Table 1-4-2 for DC should not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Clause 8 of Part 1.

Where the load is an AC electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, the break current of the load should be considered to be 50 percent of the make current of the load. The load limitations recommended in the following paragraph include provision for this situation.

Where control-circuit switches are used in a typical automatically operated sequencing system, it is recommended that the load be less than 25 percent of the make and break ratings given Table 1-4-1 and Table 1-4-2.

9.1.1.2 Semiconductor Switching Elements

The utilization categories given in Table 1-4-3 and the ratings in Table 1-4-4 and Table 1-4-5 are considered standard. Any other type of application should be based on agreement between the manufacturer and the user.

9.1.2 Contact Life

Because of the endless variety of application conditions in terms of the electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in the NEMA Standards Publication. Therefore, manufacturers' recommendations should be obtained regarding specific applications.

9.1.3 Overlapping Contacts

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally open and normally closed contacts of a control-circuit switch may or may not be conducting current simultaneously during operation. If such overlap or nonoverlap is essential, the manufacturer should be consulted.

9.1.4 Polarity

Opposite polarities should not be connected to the contacts of one control-circuit switch unless the switch is specifically designed for such service. See Figure 3-9-1.

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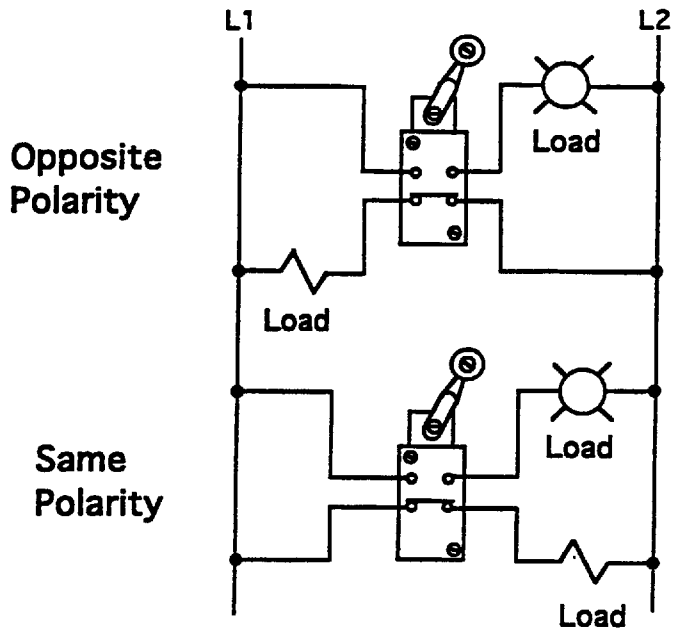


Figure 3-9-1
Polarity

9.1.5 Different Voltage Sources

Voltage from different sources should not be connected to the contacts of one control-circuit switch unless the switch is specifically designed for such service. See Figure 3-9-2.

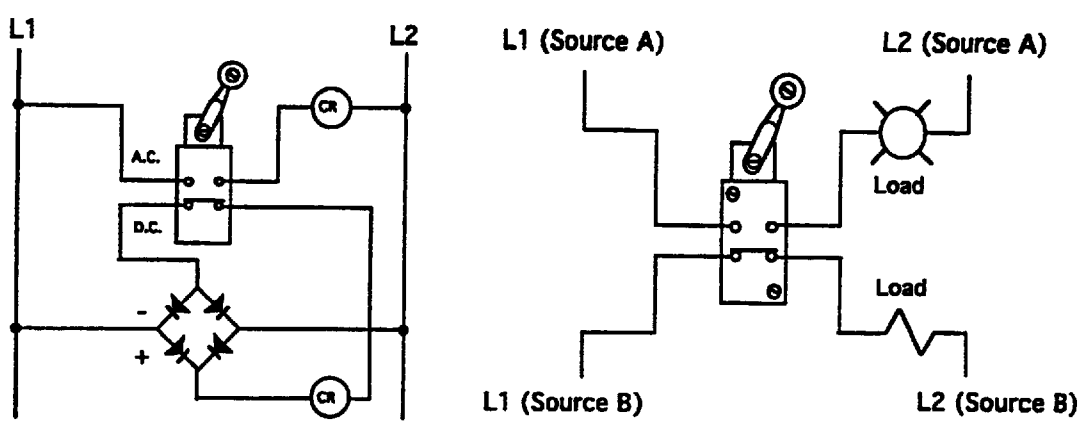


Figure 3-9-2
Different Voltage Sources

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9.1.6 Slow-Motion Operation

Where relatively slow motions operate the limit switch, the switch should be snap-acting. See Figure 3-9-3.

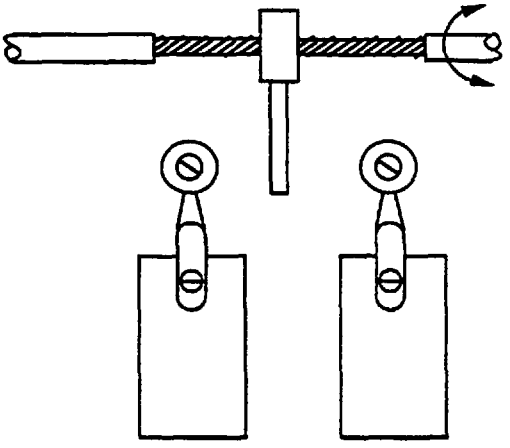


Figure 3-9-3
Typical Slow Motion Operation
(Snap-Action Limit Switches)

9.1.7 Interlocking Control-Circuit For Personnel Protection

Limit switches in some control designs, such as for metal fabrication and plastic molding, are applied in interlocking control circuits for personnel or property protection.

Where so applied, it is necessary that:

a. The limit switch be used with at least one other mechanical or electrical device that will independently serve the same interlocking function. i.e. Redundancy.

b. The control circuit be deigned so that malfunction or improper sequencing of any one interlocking device will immediately stop and prevent further operation of the controlled equipment. i.e. Checking.

c. The compatibility between the cam mechanism and the type of limit switch and actuator, along with their respective limitations and possible mechanical and electrical failure modes, be given careful consideration during design and use to maximize personnel or property protection.

d. The cam mechanism, limit switch and actuator should be routinely inspected and properly maintained.

e. For additional information, see the discussion of control reliability in ANSI B11.19-1990, *American National Standard for Machine Tools* - "Safeguarding when referenced by other B11 Machine Tool Safety Standards - Performance Criteria for the Design, Construction, Care and Operation".

9.2 Cam Design Considerations

The selection of appropriate actuating means and the design of the cam that operates the actuator of industrial type limit switches are of extreme importance to the operation and life of the switch. this clause provides a few examples of proper cam designs. When available, the manufacturer's recommendations in selecting and applying limit switches an actuators should always be followed.

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9.2.1 Fast Motion Operation

Where relatively fast motions are involved, the cam arrangement should be such that the actuator does not receive a severe or sharp impact. See Figure 3-9-4.

Where lever actuated switches are used, it is very important that an appropriate lever type is selected, and that the lever be tightened securely to prevent the lever from slipping on the shaft.

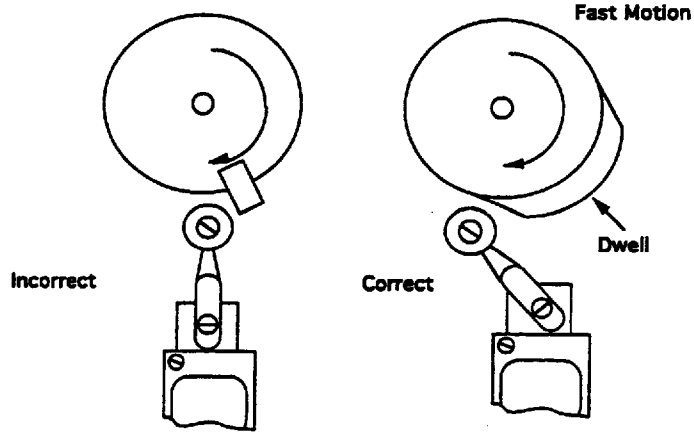


Figure 3-9-4
Cam For Fast-Motion Operation And Dwell Requirements

9.2.2 Required Actuator Travel

A limit switch actuator must move far enough for positive operation of the contacts. See figure 3-9-5.

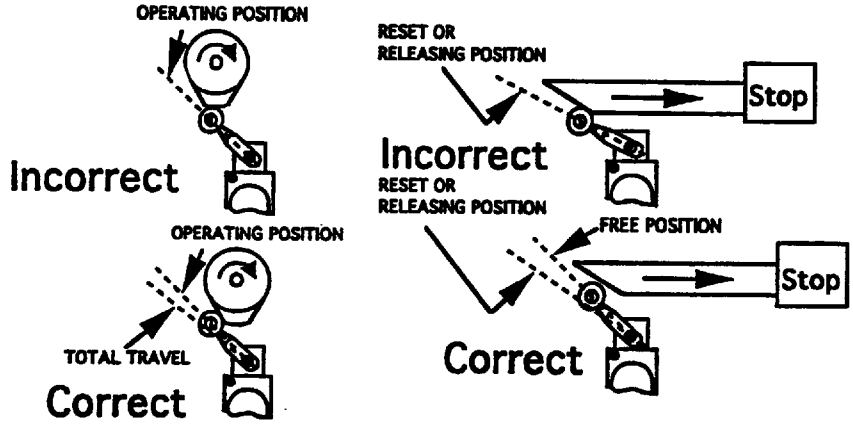


Figure 3-9-5
Actuator Travel

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9.2.3 Dwell Requirements

Where relatively fast motions are involved, the cams should be so designed that the limit switch will be held operated long enough to operate relays, valves, etc. See figure 3-9-4.

NOTE: Although this figure only shows a rotary cam, the same principle applies to linear cams as well.

9.2.4 Overtravel Limitations

Operating cams for limit switches should be so designed that, under any operating or emergency conditions, the limit switch will no be operated or forced beyond its total travel position. A limit switch should never be used as a mechanical stop.

9.3 Cam Design Recommendations

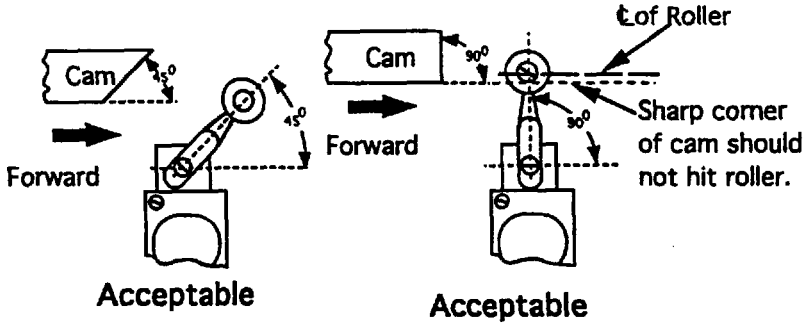
9.3.1 Lever Operated Switches

9.3.1.1 Non-Overriding Cam

For limit switches with lever actuators, the actuating force should be applied perpendicular to the shaft axis about which the lever rotates. The angle of the lever arm at rest and the angle of the leading edge of the cam should be the same, so that the force applied is perpendicular to the lever arm. See Figure 3-9-6(a).

For applications in which the cam is traveling at speeds to 90 feet/minute, the angle of the leading edge of the cam and a lever angle of 45 degrees is recommended, as shown in Figure 3-9-6(a). Using other than the recommended angles can reduce the life of the switch.

For applications, in which the cam is traveling at speeds less than 50 feet/minute, a cam and lever angle of 90 degrees, as shown in Figure 3-9-6(b), is acceptable.



(a) Cam speeds up to 90 feet/minute (b) Cam speed less than 50 feet /minute

Figure 3-9-6
Recommended Cam Angles

NOTE: Figure 3-9-6 and 3-9-7 define the relationship between the angle of the cam and the set-up position of the lever arm. For the purpose of illustration in this standard the convention is for the cam to be travelling forward from left to right. reverse this convention for cams travelling right to left.

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9.3.1.2 Non-Reversing, Overriding Cam

In overriding cam applications it is important to angle the trailing edge of the cam in order to prevent the lever arm from snapping back which may cause the false operation of the contacts known as "telegraphing". See Figure 3-9-7(a) for cam speeds up to 90 feet/minute. For higher speed applications it is recommended that the manufacturer be consulted for information on suitable cam design.

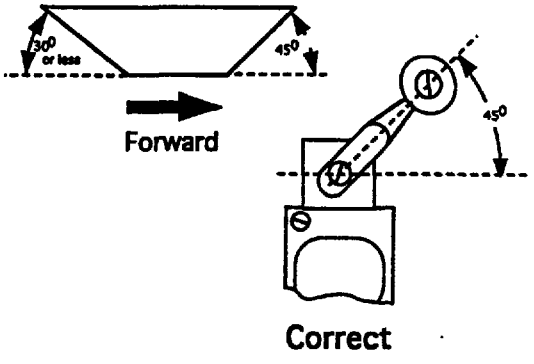


Figure 3-9-7(a)
Non-Reversing, Overriding Cam

9.3.1.3 Reversing, Overriding Cam

Some applications will require the cam to travel both forward and backward. In these instances the trailing edge cam angle should be further reduced. See Figure 3-9-7(b) for cam speeds up to 90 feet/minute. For higher speed applications it is recommended that the manufacturer be consulted for information on suitable cam design.

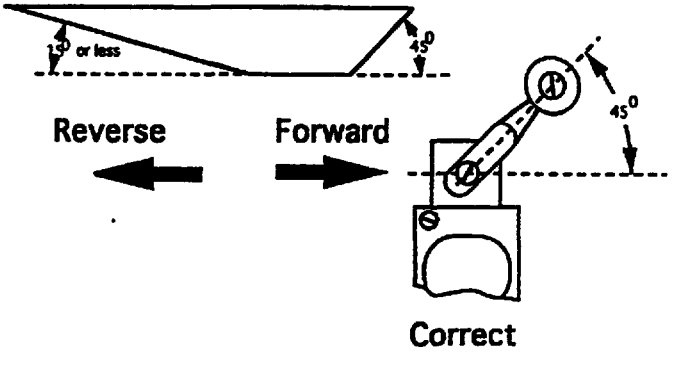


Figure 3-9-7(b)
Reversing, Overriding Cam

9.3.1.4 Rotating Cam

Roller-lever-operated limit switches may be actuated by a rotating cam. See Figure 3-9-7(c). Face-mounted studs, bolts and other similar single-point protrusions should not be sued for actuation. For cam speeds up to 90 linear feet/minute select the cam angle in the same way as shown in Figure 3-9-7(a) or

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Figure 3-9-7(b). For higher speed applications, it is recommended that the manufacturer be consulted for information on suitable cam design.

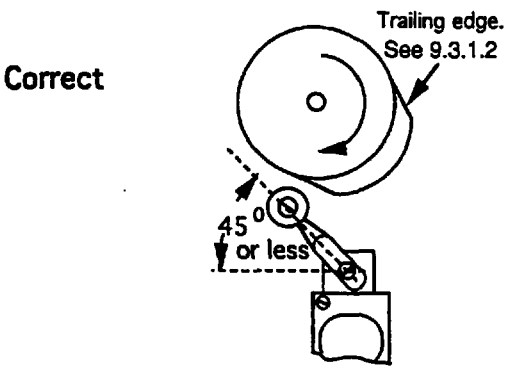


Figure 3-9-7(c)
Rotating Cam

9.3.1.5 Maintained Contact, Fork-Lever Actuated Switches

The cam should be designed to assure that the switch is pushed past its mechanical detent to its full maintained or reset position.

Fork-type (Rocker arm) levers may be used as shown in Figure 3-9-8 and Figure 3-9-9.

NOTE: One cam direction operates the switch and the other cam direction resets the switch. Cam must be narrow enough to fit between forked portion of the lever and not jam.

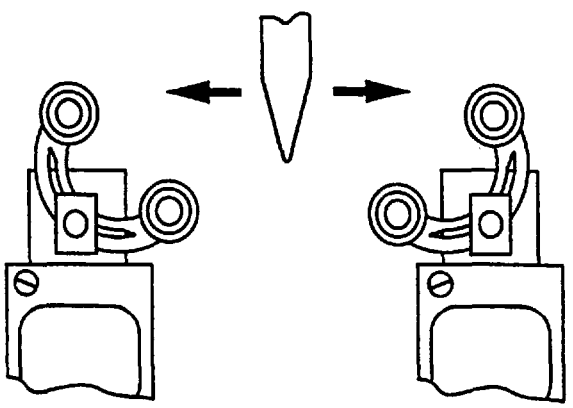


Figure 3-9-8
Fork Type Lever

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9.3.1.6 Maintained Contact, Offset Fork-Type Lever

The cams are in different planes. The right hand cam only engages the left hand roller, and the left hand cam only engages the right hand roller. See Figure 3-9-9.

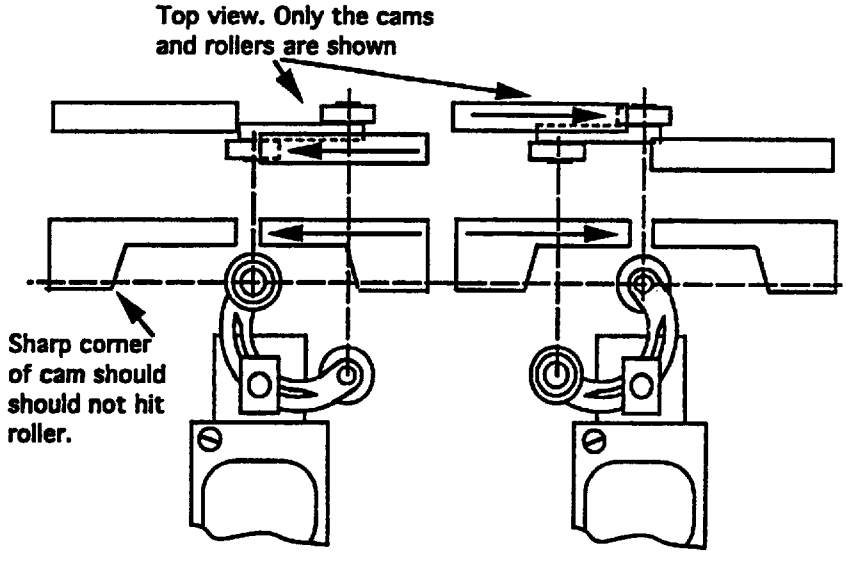


Figure 3-9-9
Offset Fork-Type Lever

9.3.2 Plunger Actuated Switches

Plunger operated limit switches are supplied with or without a roller on the end of the plunger. Plungers without rollers should be operated only by force applied in line with the operation of the plunger. Cams for roller plunger type operators should be designed with an angle on the leading edge of 30 degrees or less. this will minimize the radial force applied to the plunger. A plunger operated switch should be mounted so that its plunger is not forced beyond its overtravel limit or used as a mechanical stop. Some applications may require a mechanical stop. See Figure 3-9-10.

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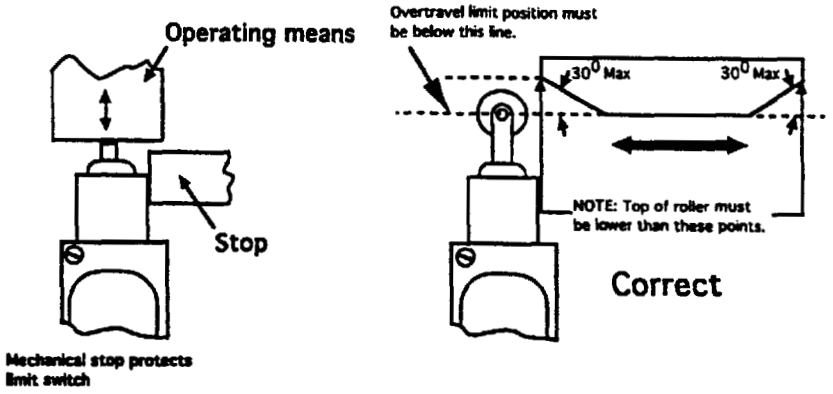


Figure 3-9-10
Plunger Actuated Switches

9.3.3 Other Types Of Operators

Limit switches are available with other types of operators such as wobble-stick, cat-whisker, etc., that are not illustrated in this application guide. When available the manufacturer's recommendations should be followed for proper application of other types of operators.

9.3.4 Supplementary Actuators

Limit switches are designed for proper performance with the actuators for which they are designed. supplementary or "homemade" actuators should not be used unless the limit switches are specifically designed to accept them. See Figure 3-9-11.

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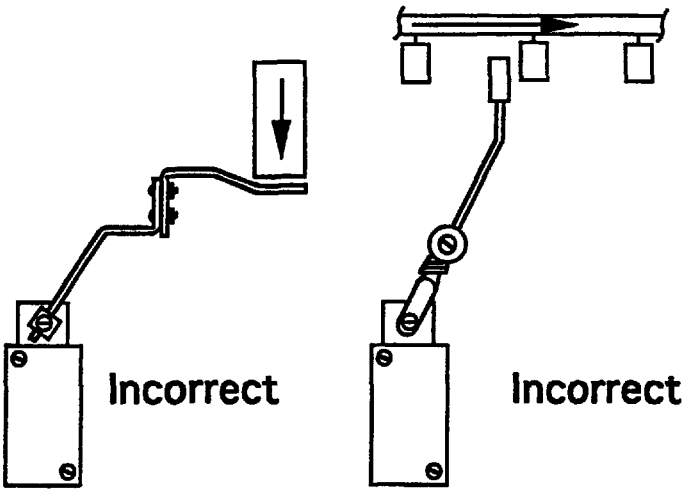


Figure 3-9-11
Supplementary Actuators

9.4 Limit Switch Location Constraints

Limit switches should be mounted so that there is no possibility of inadvertent actuation or any possibility of damage to the limit switch by moving parts of the machine or equipment, or by external sources such as fork lift trucks, etc. They should not be used as pendant, portable or hand held switches. Operation of limit switch actuator should be by designed mechanical means and not by physical human contact.

a. Limit switches should be mounted locations which will prevent false operation by movements of operator or machine components. See figure 3-9-12(a).

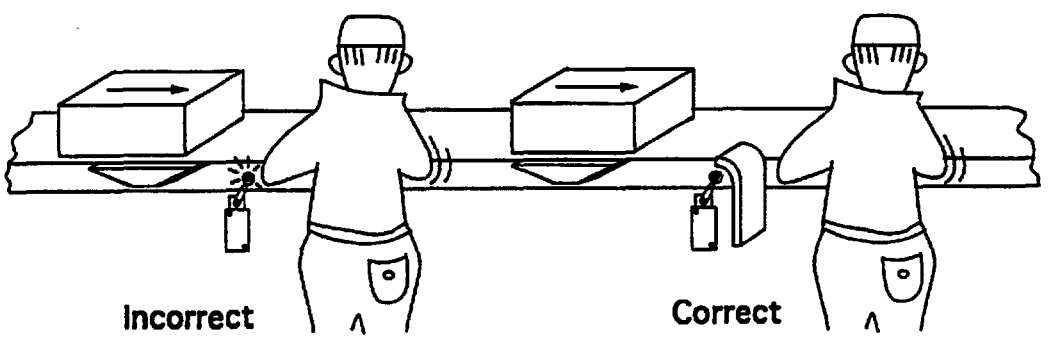


Figure 3-9-12(a)

b. Limit switches should be mounted rigidly and in readily accessible locations, with suitable clearances to permit easy service and replacement when necessary. Cover plates should face the maintenance access point. See Figure 3-9-12(b). Switch mounting tightness should be checked periodically.

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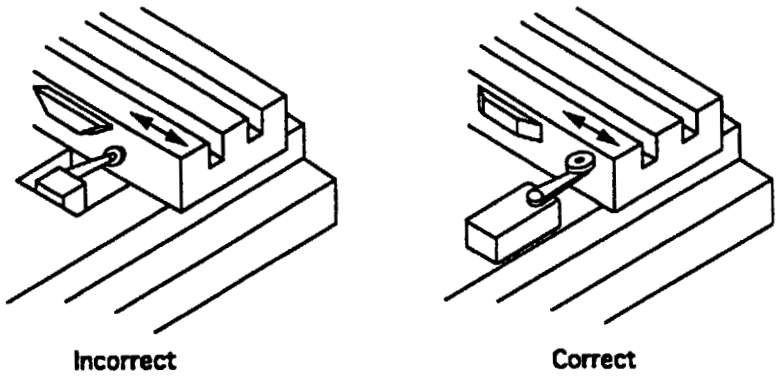


Figure 3-9-12(b)

c. Limit switches should not be submerged in or splashed with oils, coolants, or other liquids unless specifically designed for such service. See Figure 3-9-12 (c)

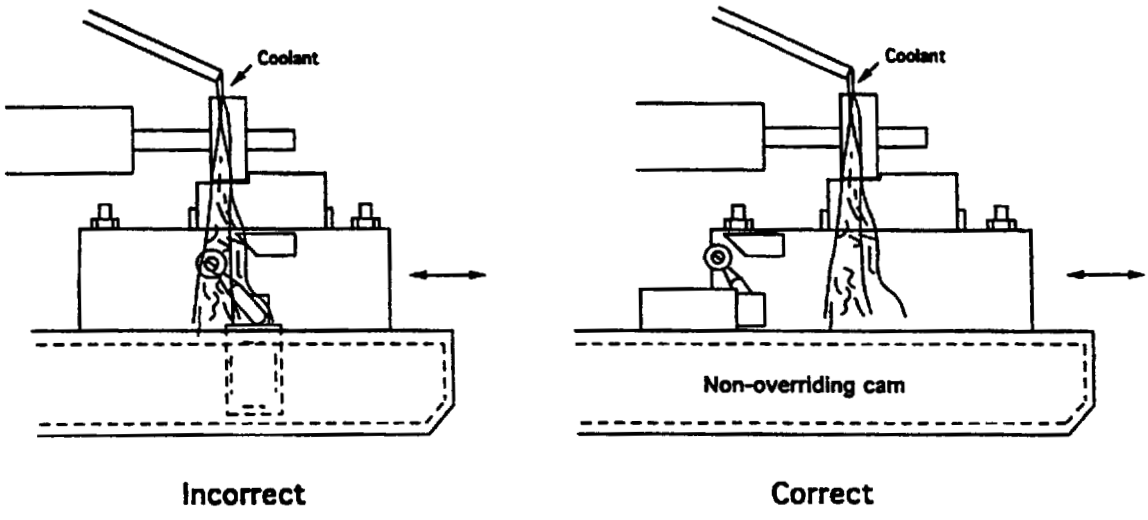


Figure 3-9-12(c)

d. Limit switches should be placed in locations where machining chips do not accumulate under normal operating conditions. See Figure 3-9-12(d).

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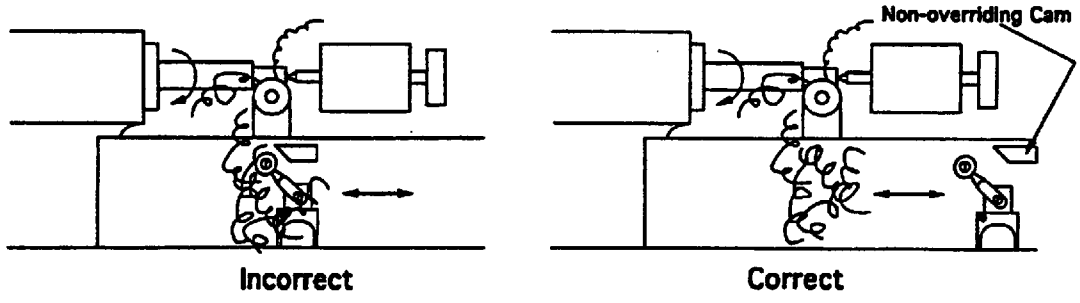


Figure 3-9-12(d)

e. Limit switches should not be used in locations where temperature or atmospheric conditions are beyond those for which they have been specifically designed. See Figure 3-9-12 (e).

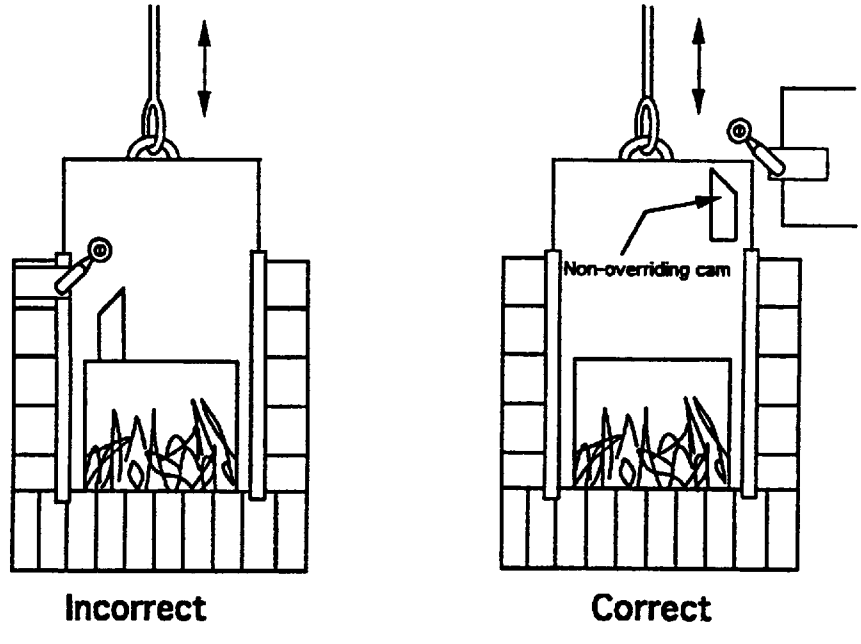


Figure 3-9-12(e)

9.5 Limit Switch Sealing

a. Sealing gaskets should be positioned properly, and all removable parts, including covers, and operating heads, etc., should be securely fastened in place before placing the switch in operation. Seals should be inspected periodically for deterioration or damage. See Figure 3-9-13.

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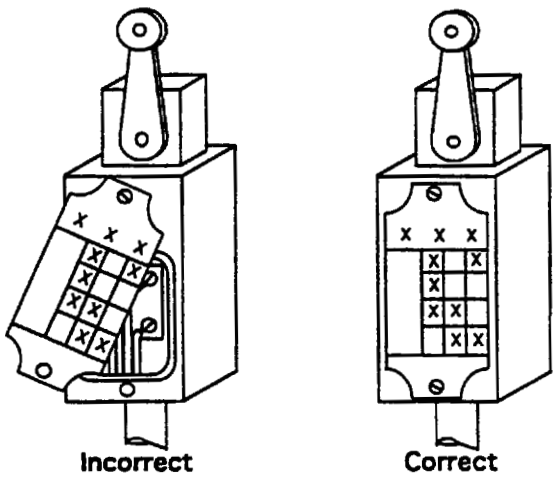


Figure 3-9-13
Limit Switch Cover Positions

b. Without maintaining tightly sealed connections liquids can sometimes reach the interior of sealed switches by way of conduit connections either by seepage into conduit junctions and junction boxes or by condensation. This may prevent proper operation. All connection points exposed to fluid should be tightly sealed. Switches should not be located at the low point of long conduit runs. See Figure 3-9-14.

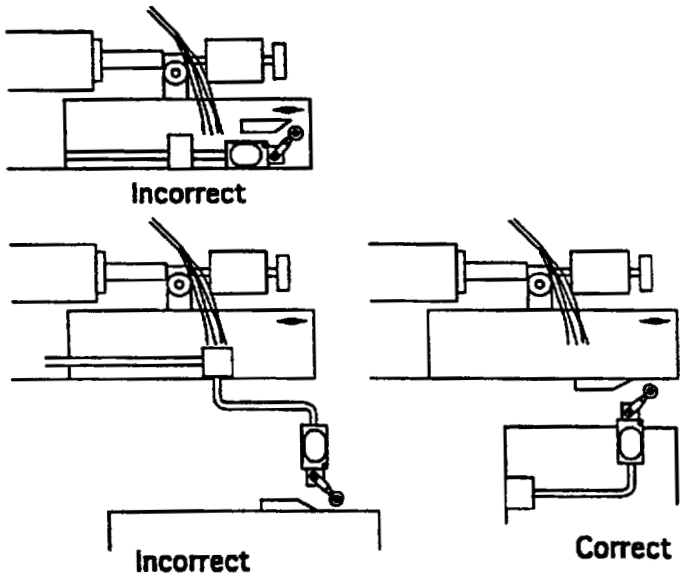


Figure 3-9-14
Seepage And Condensation Considerations

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c. Where liquids, and atmospheres containing liquids in suspension cannot be prevented from entering the conduit systems, by the use of tightly sealed connections, sealing-type fittings or switches incorporating seals should be used. See Figure 3-9-15.

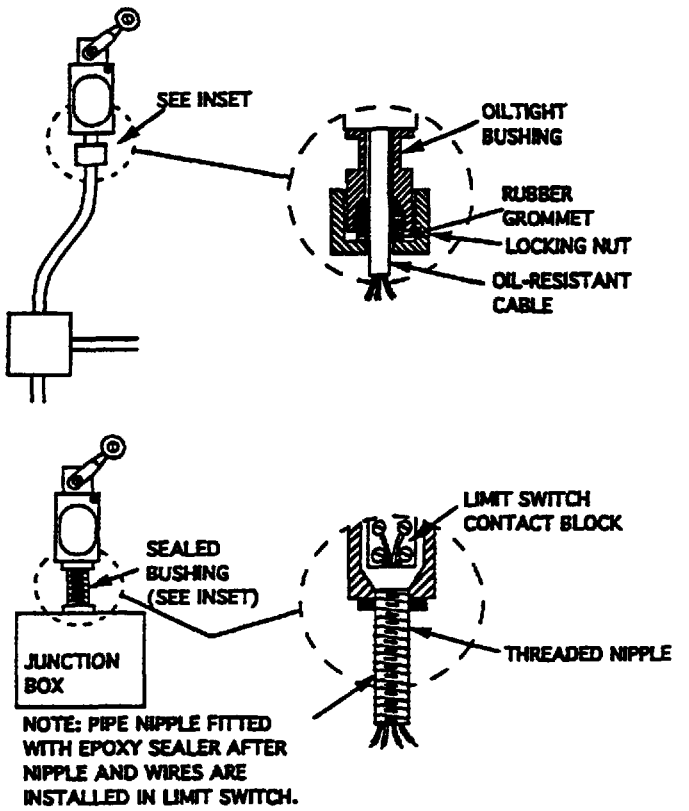


Figure 3-9-15
Sealing Fittings

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Part 4
PROXIMITY SWITCHES

1 GENERAL

1.1 Scope

The standards in this part apply to the category of control-circuit devices, known as proximity switches, that sense the presence of designated objects by means other than physical contact to include: capacitive, inductive, ultrasonic, photoelectric, and magnetic sensors.

These proximity switches are intended to be connected to circuits with rated voltages not to exceed 250 volts 50 Hz/60 hertz AC or 300 volts DC.

This standard does not apply to proximity sensors with analog outputs.

Clauses 1 to 9 contain the general requirements. Classifications of proximity switches are given in Annex A. Suggested dimensions are listed in Annex B. Annexes A and B are integral parts of this standard.

1.2 Normative References

At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below.

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, Virginia 22209

ICS 1-1993 *Industrial Control and Systems*
General Standards

ICS 5-1993 *Industrial Control and Systems*
Control-Circuit and Pilot Devices
Part 1 - *General Standards for Control-Circuit and Pilot Devices*

ICS 6-1993 *Industrial Control and Systems*
Enclosures

ICS 11-2 (1996) *Electromagnetic compatibility for industrial-process measurement and control equipment*
Part 2 - *Electrostatic discharge requirements.*

ICS 11-3 *(1996)* *Electromagnetic compatibility for industrial-process measurement and control*
Part 3 - *Radiated electromagnetic field requirements.*

ICS 11-4 *(1996)* *Electromagnetic compatibility for industrial-process measurement and control equipment equipment*
Part 4 - *Electrical fast transient/burst requirements.*

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International Electrotechnical Commission
1 rue de Varembé
Geneva, Switzerland

IEC 255-5 *Electrical Relays*
Part 5 - *Insulation tests for electrical relays*

CISPR 11 *Limits and methods of measurement of radio interference characteristics of industrial, scientific and medical (ISM) radio-frequency equipment (excluding surgical diathermy apparatus)*

1.3 List of Symbols

Referenced Symbol	Name	Page no.
EMC	Electromagnetic compatibility	59
ESD	Electrostatic discharge	59
f	Standard frequency of operation	44
H	Differential travel	41
I_e	Rated (nominal) operational current	57
I_m	Minimum operational (load) current	42
I_o	No-load supply current	42
I_r	OFF-state current	42
PLC	Programmable Logic Controller	57
R	Repeat accuracy (Repeatability)	44
s_a	Assured operating distance	41
s_d	Sensing range	44
s_n	Rated (nominal) operating distance	43
s_r	Effective operating distance	41
s_u	Usable operating distance	45
t_{off}	Turn off time	44
t_{on}	Turn on time	44
t_v	Time delay before availability (Start-up time)	44
U_b	Rated (nominal) operational voltage including tolerances	50
U_d	Maximum voltage drop	48
U_e	Rated (nominal) operational voltage	48
U_i	Rated insulation voltage	48
U_{imp}	Rated impulse withstand voltage	48

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2 DEFINITIONS

Clause 2 of ICS 5, Part 1 applies with the following additions:

Adjuster (Potentiometer):

- **of a capacitive or an inductive,proximity switch:** A part of a capacitive proximity switch used to set the operating distance. Its use compensates for influence due to target material, transmission medium and installation (mounting) conditions.
- **of a photoelectric or ultrasonic proximity switch:** A part of an inductive, photoelectric or ultrasonic proximity switch used to set the operating distance within the sensing range.

Ambient light (for a photoelectric proximity switch): For the purpose of this standard, ambient light is the light received by the receiver other than that originating from the emitter.

Assured operating distance s_a (Usable sensing range): The distance from the sensing face within which the correct operation of the proximity switch under specified conditions is assured.

Axial approach: The approach of the target with its center maintained on the reference axis.

Beam angle, total:

- **for a photoelectric proximity switch:** A measure of the spatial distribution of emitted energy; the total angle between half-intensity points including the optical axis.
- **for an ultrasonic proximity switch:** Solid angle around the reference axis of an ultrasonic proximity switch where the source level drops by 3 dB.

Blind zone: The zone between the sensing face and the minimum operating distance where no object can be detected.

Break function (normally closed): A function which causes load current not to flow when a target is detected and load current to flow when a target is not detected.

Capacitive proximity switch: A proximity switch producing an electrostatic field which senses all materials within a sensing zone.

Damping material: A material which has an influence on the characteristics of a proximity switch.

Dark operation: An operation of photoelectric switches which causes the output to be energized when light is not detected by the receiver, and output to be deenergized when light is detected by the receiver.

Differential travel H (Hysteresis): The distance between the operating point as the target approaches the proximity switch and the release point as the target moves away.

Effective operating distance s_r: The operating distance of an individual proximity switch, measured at stated temperature, voltage and mounting conditions.

Embeddable (shielded) proximity switch: A switch which can be mounted with any damping material placed around the sensing face plane without adversely influencing the switch characteristics.

Emitter: The light source, lens and necessary circuitry which provide the light beam.

Excess gain (margin) for a photoelectric proximity switch: The ratio of the light intensity received by the photoelectric proximity switch and the light intensity required to operate the photoelectric proximity switch.

Free zone: A space around the proximity switch which is kept free from any material capable of affecting the characteristics of the proximity switch.

Independent (snap) action: A switching element function substantially independent from the velocity of the target.

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Inductive proximity switch: A proximity switch producing an electromagnetic field which senses only metal targets within a sensing zone.

Lateral approach: The approach of the target perpendicular to the reference axis.

Light operation: An operation of photoelectric switches which causes the output to energize when light is detected by the receiver, and the output to deenergize when light is not detected by the receiver.

Magnetic proximity switch: A proximity switch which senses the change in a constant magnetic field.

Make function (normally open): A function which causes load current to flow when a target is detected and load current not to flow when a target is not detected.

Make-break function (complimentary, normally open/normally closed): A switching element combination which contains one make function and one break function.

Maximum operating distance: The upper limit of the specified sensing range.

Minimum operating distance: The lower limit of the specified sensing range.

Minimum operational (load) current I_m: The current that is necessary to maintain ON-state conduction of the switching element.

No-load supply current I_o: The supply current required by a 3 or 4 terminal proximity switch when not connected to a load.

Nondamping material: A material which has negligible influence on the characteristics of a proximity switch.

Non-embeddable (unshielded) proximity switch: A proximity switch is nonembeddable when a specified free zone around its sensing face is necessary in order to maintain its characteristics.

N-type, NPN, current sinking: A DC 3-wire switch that switches the load between the output terminal and the negative supply terminal.

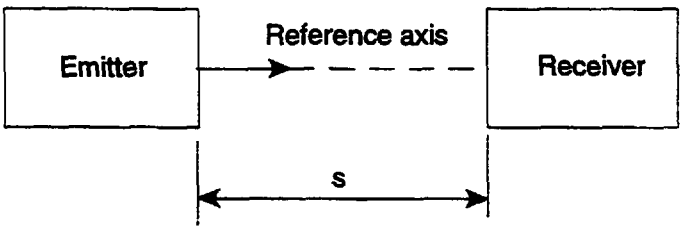
OFF-state current I_r: The current which flows through the load circuit of the proximity switch in the OFF-state. This current is also known as leakage, burden or residual current in two-wire devices, and as leakage or residual current in three-wire devices.

Operating distance: A distance at which the target approaching the sensing face along the reference axis causes the output signal to change.

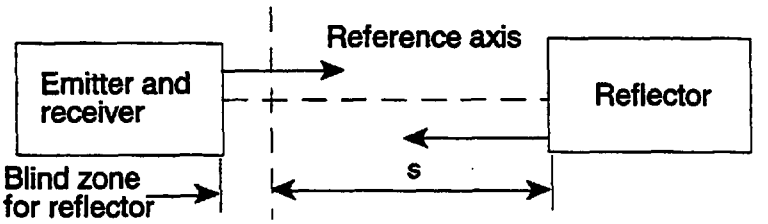
For Types T and R photoelectric: the distance between the emitter and the receiver, or retroreflector.

Photoelectric proximity switch: A proximity switch which senses objects that either reflect or interrupt visible or invisible light. (See Figure 4-3-1)

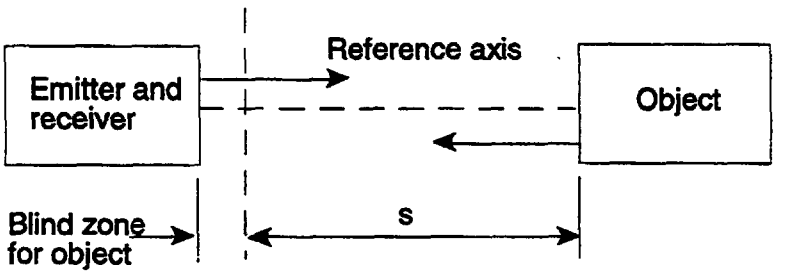
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(a) Type T, emitter and receiver - Through beam photoelectric



(b) Type R, emitter-receiver and reflector - Retroreflective photoelectric



(c) Type D, emitter-receiver and object - Diffuse reflective photoelectric

Figure 4-2-1
Sensing range (s_d) of photoelectric proximity switches

Proximity switch: A position switch which senses a target without mechanical contact with the target.

P-type, PNP, current sourcing proximity switch: A DC 3-wire switch that switches the load between the positive supply terminal and the output terminal.

Rated (nominal) operating distance s_n: The rated operating distance is a conventional quantity used to designate the operating distances. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature.

Receiver: The detector and necessary circuitry to monitor the signal from the emitter.

Reference axis:

- **for inductive, capacitive, magnetic and ultrasonic proximity switches:** An axis perpendicular to the sensing face and passing through its center.

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– **for retroreflective (type R) and diffuse reflective (type D) photoelectric proximity switches:** An axis located midway between the optical axis of the emitter and receiver elements or lenses (see Figure 4-3-1).

– **for through beam (type T) photoelectric proximity switches:** An axis perpendicular to the center of the emitter. (see Figure 4-2-1).

Reflector: A specified device used to reflect light back to the receiver for Type R photoelectric proximity switches.

Repeat accuracy R (Repeatability): The value of variation of the effective operating distance s_r under specified conditions.

Response time: The time required for the device switching element to respond after the target enters or exits the sensing zone.

Sensing face:

– **of an inductive proximity switch:** A surface of the proximity switch through which the electromagnetic field emerges.

– **of a capacitive proximity switch:** A surface of the proximity switch through which the electric field emerges.

– **of an ultrasonic proximity switch:** A surface of the proximity switch where ultrasound is transmitted and received.

– **of a magnetic proximity switch:** A surface of the proximity switch through which the change in a magnetic field is determined.

Sensing range s_d: The range within which the operating distance may be adjusted.

Semiconductor switching element: An element designed to switch the current of an electric circuit by controlling conductivity of a semiconductor.

Sound absorbing material: A material with negligible reflecting characteristics for ultrasound waves which gives no detectable echo.

Sound reflecting material: A material which reflects the ultrasound waves and gives detectable echoes.

Standard frequency of operation: Maximum number of operating cycles performed by a proximity switch in a specified period of time.

Standard target: A specified target used for making comparative measurements of the operating distances and sensing distances.

Time delay before availability t_v (Power-up delay): The time interval from when the supply voltage being applied to a proximity switch and when the switch is ready to operate correctly.

Three-wire proximity switch: An AC or DC proximity switch with three leads, two of which supply power and a third that switches the load. A DC three-wire type proximity switch switches the load between the positive supply terminal or the negative supply terminal.

Turn off time, t_{off} (proximity switch): The time required for the switching element to respond after the target exits the sensing range.

Turn on time, t_{on} (proximity switch): The time required for the switching element to respond after the target enters the sensing range.

Two-wire proximity switch: A proximity switch which has only two leads and switches a series connected load to the power supply. Power for the proximity switch is obtained through the load at all times.

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Ultrasonic proximity switch: A proximity switch which senses objects within a sensing zone that either eflect or interrupt ultrasound waves. (See Figure 4-2-2)

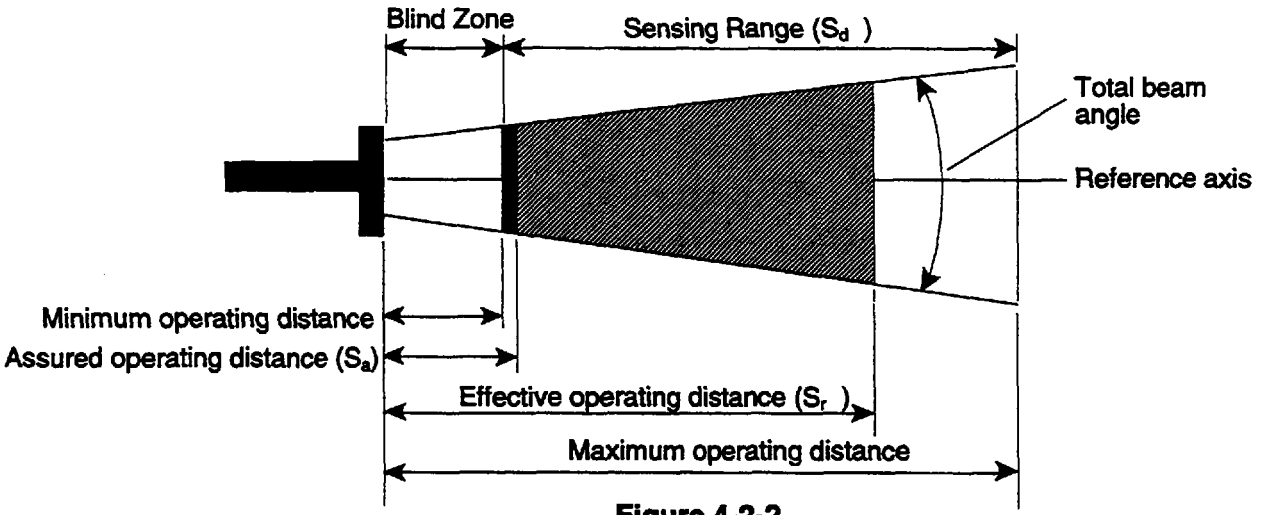


Figure 4-2-2
Ultrasonic Proximity Switch Operating Distances

Usable operating distance s_u: The usable operating distance is the operating distance of an individual proximity switch, measured under specified conditions.

CLASSIFICATION

See Annex A for optional classifications.

4 CHARACTERISTICS

4.1 Summary Of Characteristics

The characteristics of a proximity switch shall be stated in the following terms:

- Operating conditions (4.2)
- Rated and limiting values (4.3)
- Voltages (4.3.1)
- Currents (4.3.2)
- Rated supply frequency (4.3.3)
- Standard frequency of operation (4.3.4)
- Normal load and abnormal load characteristics (4.3.5)
- Short-circuit characteristics (4.3.6)
- Utilization categories for the switching element (4.4).

4.1.1 Operation Of An Inductive Or Capacitive Proximity Switch

The output signal is determined by the presence or absence of a target in the electromagnetic or electric field which absorbs or alters energy radiated from the sensing face.

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4.1.2 Operation Of An Ultrasonic Proximity Switch

The output signal is determined by the presence or absence of a target in the sensing zone which reflects or interrupts ultrasound energy radiated from the sensing face.

4.1.3 Operation Of A Photoelectric Proximity Switch

The output signal is determined by the presence or absence of a target that either reflects or interrupts visible or invisible light radiated from the emitter.

4.1.4 Operation Of A Magnetic Proximity Switch

The output signal is determined by the presence or absence of a target which produces a change in a magnetic field within the sensing zone.

4.2 Operating Conditions

4.2.1 Operating Distance(S) Of Inductive And Capacitive Proximity Switches

The relationship between the operating distances is shown in Figure 4-4-1.

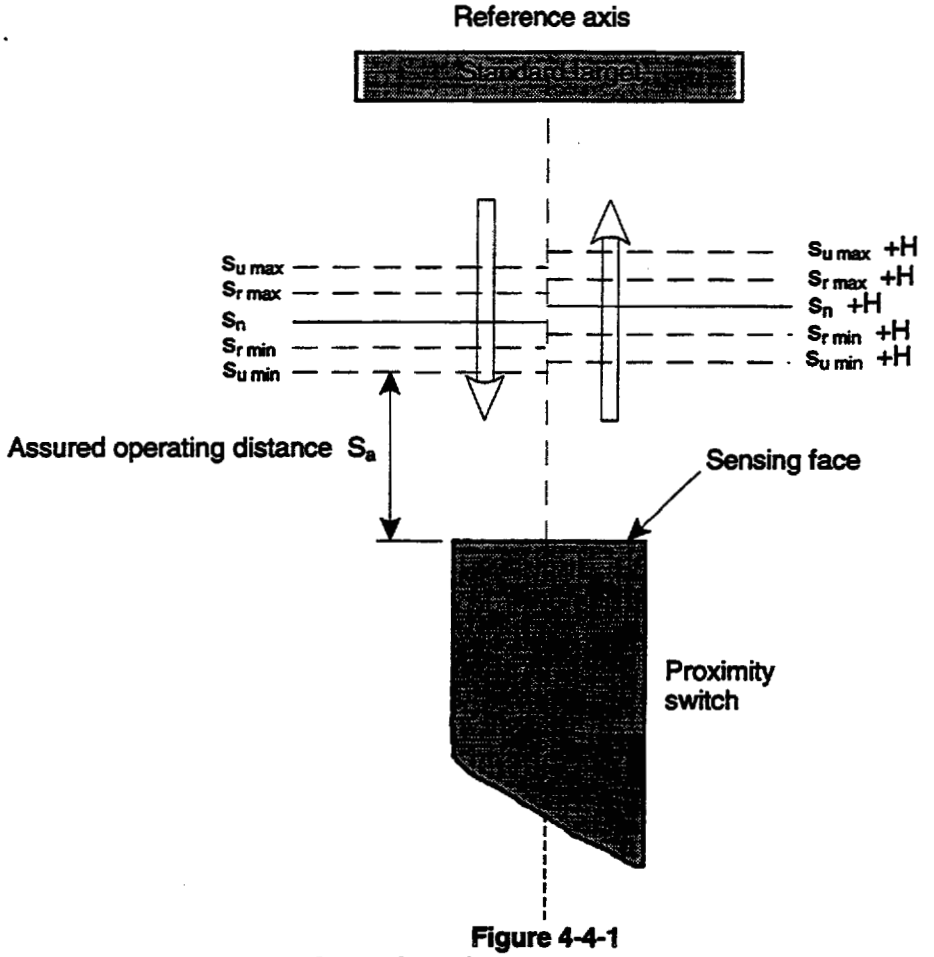


Figure 4-4-1
Relationship Between Operating Distances Of Inductive, Capacitive And Magnetic Proximity Switches

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4.2.1.1 Rated Operating Distance S_n

Rated operating distances are specified by the manufacturer. Typical rated operating distances may be found in Annex B.

Operating distance(s) of an ultrasonic proximity switch

The relationship between the operating distances is shown in Figure 4-4-2.

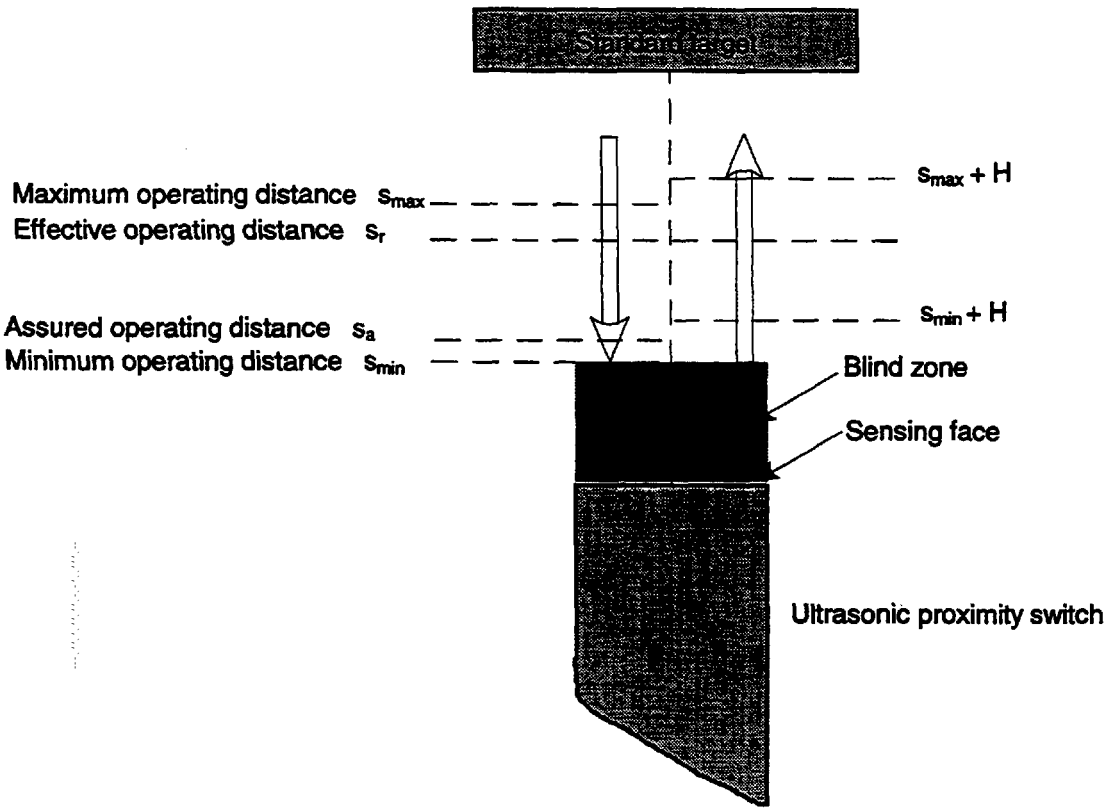


Figure 4-4-2
Relationship Between Operating Distances Of Ultrasonic Proximity Switches

4.2.1.2 Sensing Range s_d

Sensing range values are given in the relevant annexes.

4.2.2 Operating Distance(S) Of A Photoelectric Proximity Switch

4.2.2.1 Sensing Range s_d

For photoelectric proximity switches the operating distances are given as the sensing range (s_d).

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4.3 Rated (Nominal) And Limiting Values For The Proximity Switch And Switching Element(S)

4.3.1 Voltages

The proximity switch and its switching element(s) are defined by the following rated voltages:

4.3.1.1 Rated (Nominal) Operational Voltage U_e

The rated operational voltage U_e (or range) shall not exceed 250 volts AC or 300 volts DC.

NOTE - The manufacturer may state a range between the limiting values which include all the tolerances of U_e, this range shall be designated U_B.

The relationship between U_e and U_B is shown in Figure 4-4-3.

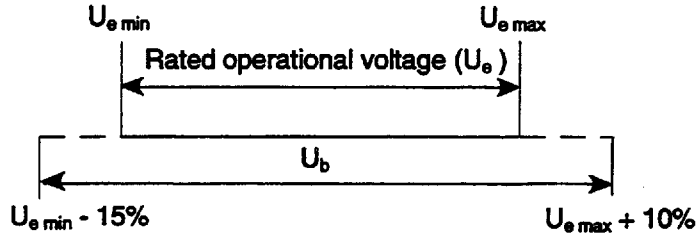


Figure 4-4-3
Relationship Between Rated Operational Voltage U_e, and Operational Voltage Range U_B

4.3.1.2 Rated Insulation Voltage U_i

The rated insulation voltage of a proximity switch is the value of voltage to which the dielectric voltage tests and creepage distances are referred. See ICS 1.

In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

4.3.1.3 Rated Impulse Withstand Voltage U_{imp}

Where the rated impulse withstand voltage is declared by the manufacturer it shall be at least 1 kV, and it shall be in accordance with Annex A of ICS 1.

4.3.1.4 Maximum Voltage Drop U_d

The maximum voltage drop is the voltage measured across the energized output of the proximity switch under specified conditions. The values are specified in 7.2.1.15.

4.3.2 Currents

The proximity switch and its switching element are defined by the following currents.

4.3.2.1 Rated Operational Current I_e

See 7.2.1.11.

4.3.2.2 Minimum Operational Current I_m

See 7.2.1.12.

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4.3.2.3 OFF-state Current I_r

See 7.2.1.13.

4.3.2.4 No-Load Supply Current I_o

The no-load supply current of a three or four terminal proximity switch shall be stated by the manufacturer.

4.3.3 Rated Supply Frequency

The rated supply frequency shall be 60 hertz or 50 hertz or both.

4.3.4 Standard Frequency Of Operation f

The standard frequency of operation shall be in accordance with the relevant annexes or stated by the manufacturer.

4.3.5 Normal Load And Abnormal Load Characteristics

4.3.5.1 Rated Making And Breaking Capacities And Behavior Of Switching Element Under Normal Conditions

A semiconductor switching element shall comply with the requirements given in Clause 8.3 of Part 1 and Table 1-8-2.

An electromechanical switching element shall comply with the requirements given in Clause 8.2 of Part 1 and Tables 1-4-1 and 1-4-2.

NOTE - For a switching element to which a utilization category is assigned, it is not necessary to specify separately a making and breaking capacity.

4.3.5.2 Making and breaking capacities under abnormal conditions

A semiconductor switching element shall comply with the requirements given in Clause 8.3 and Table 1-8-3 of Part 1.

NOTE - For a switching element to which a utilization category is assigned, it is not necessary to specify separately a making and breaking capacity.

4.3.6 Short-Circuit Characteristics

4.3.6.1 Rated Conditional Short-Circuit Current

The rated conditional short-circuit current of a proximity switch is 100 amperes minimum prospective. The proximity switch shall withstand the test specified in 8.3.4.

4.4 Utilization Categories For The Switching Element

The utilization categories as given in Table 1-4-3 in Part 1 of ICS 5 are considered standard. Any other type of application shall be based on agreement, between manufacturer and user, but information given in manufacturer's catalog may constitute such an agreement.

5 PRODUCT INFORMATION

5.1 Nature Of Information

The following information shall be given by the manufacturer.

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5.1.1 Identification

a. The manufacturer's name or trade mark.

b. A part number, type designation (see Table A-1) or other marking which makes it possible to identify the proximity switch and get the relevant information from the manufacturer or his catalog.

c. Reference to this standard if the manufacturer claims compliance.

5.1.2 Specifications

a. Operational Voltage Range, U_B, or for single voltage rated devices U_e (see 4.3.1.1).

b. Utilization category and rated operational currents at the rated operational voltages and frequencies AC, or at the rated operational voltages DC.

c. Rated insulation voltage (see 4.3.1.2).

d. Rated impulse withstand voltage (see 4.3.1.3).

e. Enclosure rating (see 7.1.8).

f. Pollution degree (see 6.1.3.2).

g. Type and maximum ratings of short-circuit protective device for proximity switches not integrally protected (see 7.2.5).

h. Rated conditional short-circuit current (see 4.3.6.1).

i. Electromagnetic compatibility (EMC) (see 7.2.6).

j. Operating distances (see 7.2.1.3).

k. Repeat accuracy (see 7.2.1.4).

l. Differential travel (see 7.2.1.5).

m. Standard frequency of operation (see 7.2.1.6).

n. Minimum operational current (see 7.2.1.12).

o. OFF-state current (see 4.2.1.13).

p. No-load supply current (see 4.3.2.4).

q. Voltage drop (see 7.2.1.15).

r. Switching element function

s. Mounting application, embeddable or non-embeddable.

t. Physical dimensions (see Annex B).

u. Excess gain (see 7.2.1.10).

5.2 Marking

5.2.1 General

Marking of data under a) and b) of 5.1.1 is mandatory on the nameplate or marked on the body of the proximity switch in order to permit the complete information to be obtained from the manufacturer.

Cylindrical proximity switches of 12 mm or smaller body diameter may provide this marking on the cord or on a tag permanently attached to the cord, located no further than 100 mm from the body of the device.

Marking shall be indelible and easily legible, and shall be placed on parts not normally removable in service.

Information required in 5.1.1 and 5.1.2, when not included on the proximity switch, shall be included in the manufacturer's literature.

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5.2.2 Terminal Identification And Marking

See 7.1.3.2.

5.2.3 Functional Markings

The sensing face shall be marked where this is not apparent by the construction of the proximity switch.

5.3 Instruction For Installation, Operation And Maintenance

The manufacturer shall specify in his instructional literature or catalogs the conditions for installation, operation and maintenance of the proximity switch, including wiring diagram.

The above documents shall indicate the recommended extent and frequency of maintenance, if any.

6 SERVICE, MOUNTING AND TRANSPORT CONDITIONS

6.1 Normal Service Conditions (Temperature, Altitude, Climatic)

The operating characteristics of proximity switches complying with this standard shall be maintained under the following standard conditions.

6.1.1 Ambient Air Temperature (Operating Temperature Range)

6.1.1.1 Inductive, Capacitive, Magnetic And Ultrasonic Proximity Switches

These proximity switches shall operate between the ambient temperatures of –25°C to +70°C.

6.1.1.2 Photoelectric Proximity Switch

Photoelectric proximity switches shall operate between the ambient temperatures of –5°C to +55°C.

6.1.2 Altitude

Proximity switches covered in this standard shall meet Altitude Class 2 km. Altitude Class 2 km designates equipment for installation where the altitude does not exceed 2000 meters (6600 feet).

6.1.3 Climatic Conditions

6.1.3.1 Humidity

The relative humidity (RH) of the air shall be within the range of 5 percent to 95 percent, noncondensing.

6.1.3.2 Pollution Degree

Unless otherwise stated by the manufacturer, a proximity switch is intended for installation under environmental conditions of pollution degree 3 as defined in ICS 1, Annex A.

6.2 Conditions During Transport And Storage

The manufacturer shall state the conditions for transport and storage, e.g. temperature and humidity, if they differ from those defined in 6.1.

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6.3 Mounting

Mounting dimensions and conditions may be according to the relevant specification sheet of annex A, or as stated by the manufacturer.

7 CONSTRUCTION AND PERFORMANCE REQUIREMENTS

7.1 Construction Requirements

7.1.1 Clearances And Creepage Distances

When the manufacturer declares a rated impulse withstand voltage, U_{imp}, Annex A of ICS 1 applies. If no value for U_{imp} has been declared, the requirements of 7.2.3 apply.

7.1.2 Indicating Means

Proximity switches may incorporate indicator lights to describe functions such as:

a. Power on—preferred color: green
b. Status of switching element—preferred color: yellow
c. Other functions—prefered colors are not specified, and variations to include flashing may be used.

7.1.3 Terminals

7.1.3.1 Connection Means

Clause 7 of Part 1 and ICS 1 apply with the following additions:

Proximity switches may have integral connecting leads; in this case the minimum length of the outer sheath of the connecting leads should be 2 m (6.6 ft).

Cables and connectors are rated for use in the same micro-environment as the proximity switch.

7.1.3.2 Connection Identification And Marking

Proximity switches with integral connecting leads shall have wires identified with colors according to Table 4-8-1.

Proximity switches with terminal connections shall be identified according to Table 4-7-1.

7.1.4 Provisions For Protective Grounding

ICS 1, Clause 7 applies with the following additions.

For proximity switches having double insulation, the outside metal enclosure is not required to be connected to the grounding terminal.

Proximity switches with maximum rated voltages not exceeding either 30 volts AC or 42.4 volts DC need no provision for grounding.

7.1.5 Enclosure Rating

Proximity switches, when installed in accordance with the manufacturer's instruction shall have at least a Type 1 enclosure rating.

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Table 4-7-1
Connection And Wiring Identification

Type	Function	Polarity/Wire Color	Wiring Terminal Numbers
2 terminals AC, and	NO (make)	Any color except yellow, green or green-and-yellow	3
2 terminals DC unpolarized			4
	NC (break)		1
			2
2 terminals DC polarized	NO (make)	+ Brown	1
		– Blue	4
	NC (break)	+ Brown	1
		– Blue	2
3 terminals DC polarized	NO (make)	+ Brown	1
		– Blue	3
		Black	4
	NC (break)	+ Brown	1
		– Blue	3
	Output	Black	2
3 Terminal AC and 3 Terminal AC/DC	NO (make)	L1 Brown	1
		L2 (neutral)/Blue	3
	Output	Black	4
	NC (break)	L1 Brown	1
		L2 (neutral)/Blue	3
	Output	Black	2
4 terminals DC	(Make/Break)	+ Brown	1
Complimentary NO/NC polarized		– Blue	3
	NO output	Black	4
	NC output	White	2

NOTE - The bi-color of green-and-yellow (green/yellow) or green color shall be used only to identify the grounding conductor. To maintain the integrity of grounding circuit, the color green shall not be used for any other purpose than to identify the grounding circuit conductor.

7.1.6 Physical Dimensions

For proximity switches with standardized physical dimensions, the dimensions are given in the relevant section of Annex B.

NOTE - Proximity switches with other dimensions are also covered by this standard.

7.2 Performance Requirements

The following requirements apply to clean new equipment.

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7.2.1 Operating Conditions

7.2.1.1 General

The equipment shall be mounted in accordance with the manufacturer's instructions. In the absence of manufacturer's instructions, the information in Annex B may be used for mounting instructions.

For the tests of 7.2.1.3 through 7.2.1.6 the load shall be adjusted to provide 20 percent of I_e.

7.2.1.2 Operating Limits

The proximity switch shall operate:

a. between 85 percent and 110 percent of U_e, or

b. between 85 percent $U_{e\,min}$ and 110 percent of $U_{e\,max}$, or

c. over the range U_B

For DC, the value of the ripple voltage (peak to peak) shall not exceed 10 percent U_e. (see 4.3.1.1).

7.2.1.3 Operating Distances

The operating distances are measured according to 8.4. The operating distances are stated when the standard target is moving towards the proximity switch in an axial approach.

For inductive and capacitive and magnetic proximity switches, the relationship between the operating distances is shown In Figure 4-4-1.

For ultrasonic proximity switches, the relationship between the operating distances is shown in Figure 4-4-2.

For photoelectric proximity switches, the relationship between the operating distances is shown in Figure 4-2-1.

7.2.1.3.1 Effective Operating Distance s_r

The effective operating distance s_r is measured at the rated voltage and at an ambient temperature of 23°C ±5°C.

For inductive and capacitive and magnetic proximity switches s_r shall be between 90 percent and 110 percent of the rated operating distance s_n:

$$0.9\, s_n \leq s_r \leq 1.1\, s_n$$

For ultrasonic proximity switches s_r shall be any distance between the minimum and maximum operating distances:

$$s_{min} \leq s_r \leq s_{max}$$

7.2.1.3.2 Usable Operating Distance s_u

Usable operating distance s_u is measured over the ambient temperature range and the supply voltage at 85 percent and 110 percent of their rated value.

For inductive, magnetic and ultrasonic proximity switches, s_u shall be between 90 percent and 110 percent of the effective operating distance s_r:

$$0.9\, s_r \leq s_u \leq 1.1\, s_r$$

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For capacitive proximity switches, s_u shall be between 80 percent and 120 percent of the effective operating distance s_r:

$$0.8\, s_r \leq s_u \leq 1.2\, s_r$$

7.2.1.3.3 Assured Operating Distance s_a

For inductive proximity switches, the assured operating distance s_a is between 0 percent and 81 percent of the rated operating distance s_n:

$$0 \leq s_a \leq 0.81\, s_n$$

For capacitive proximity switches, the assured operating distance s_a is between 0 percent and 72 percent of the rated operating distance s_n:

$$0 \leq s_a \leq 0.72\, s_n$$

7.2.1.3.4 Sensing Range s_d For Photoelectric Proximity Switches

The sensing range s_d is measured according to 9.4.2. The sensing range is shown:

a) in Figure 4-7-1a for through beam (Type T): Emitter and Receiver,

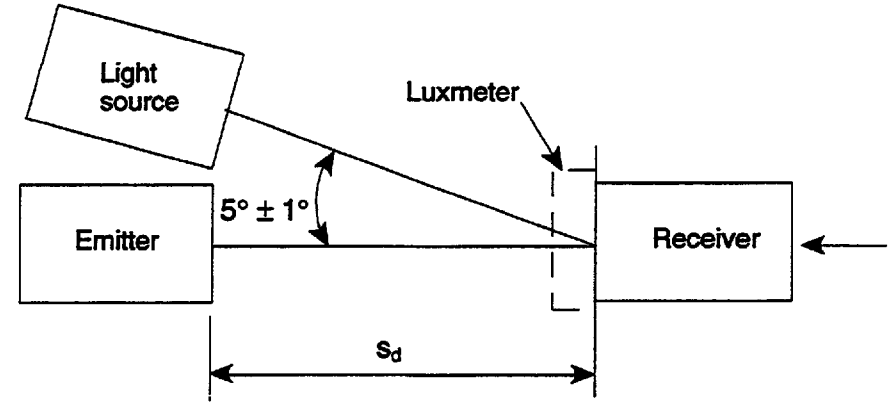
b) in Figure 4-7-1b for retroreflective (Type R): Emitter, Receiver and Reflector,

c) in Figure 4-7-1c for diffuse reflective (Type D): Emitter, Receiver and Target.

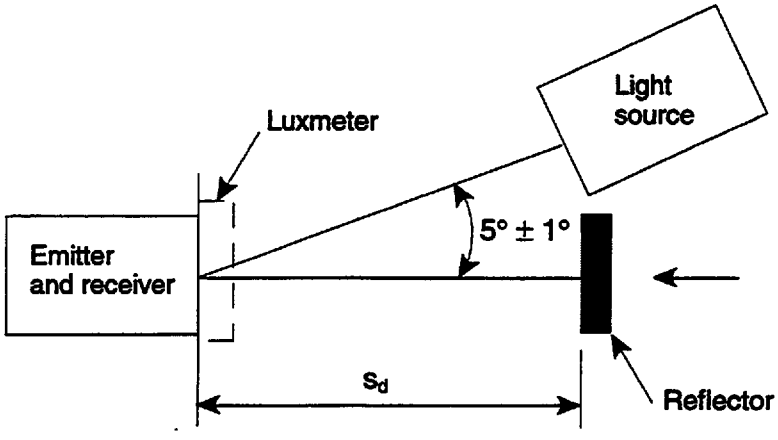
The sensing range is stated by the manufacturer for 0 lux and

5000 lux of ambient light according to the test method specified in 8.4.2.

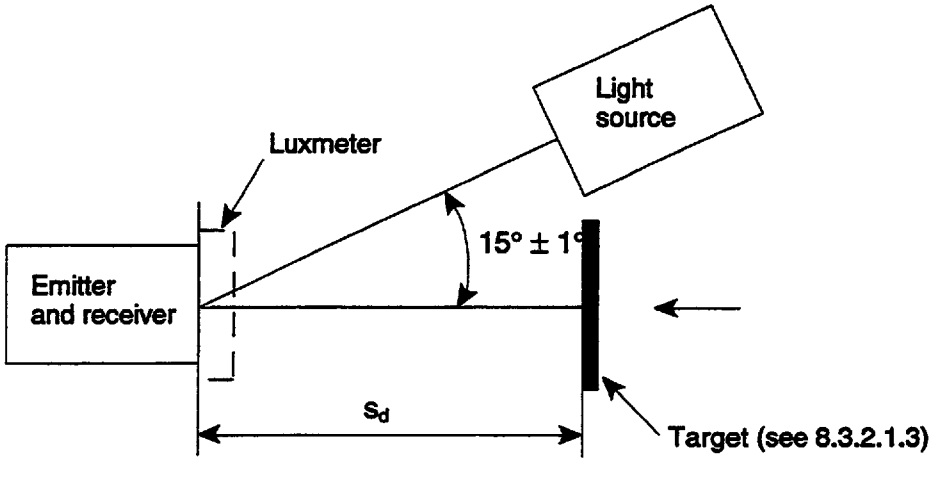
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(a) Type T, emitter and receiver



(b) Type R, emitter - receiver and reflector



(c) Type D, emitter - receiver and object

Figure 4-7-1
Sensing Range of a Photoelectric Proximity Switch

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.2.1.4 Repeat accuracy, R

The repeat accuracy, R, of the effective operating distance s_r is measured, in accordance with 8.4.1.5.

The difference between any two measurements shall not exceed 10 percent of the effective operating distance s_r:

$$R \leq 0.1\ s_r$$

7.2.1.5 Differential Travel H

The differential travel H is given as a percentage of the effective operating distance s_r. The measurement is made in accordance with 9.4.1.3 at an ambient temperature of 23°C ±5°C and at the rated supply voltage. It shall be less than 20 percent of the effective operating distance s_r:

$$H < 0.2\ s_r$$

7.2.1.6 Standard Frequency Of Operation f

The standard frequency of operation shall be in accordance with the relevant annexes, or as stated by the manufacturer, and shall be measured according to 8.5.

7.2.1.7 Time Delay Before Availability t_v (Start-Up Time)

The time delay before availability shall not exceed 300 ms, and shall be verified in accordance with 8.3.3.2.1. During this time the switching element shall not give any false signal. A false signal is a signal other than zero which appears for longer than 2 ms.

NOTE - Zero signal means that only OFF-state current flows through the load.

.2.1.8 Turn On time t_{on}

The turn on time shall be stated by the manufacturer and measured according to 8.5.

7.2.1.9 Turn Off Time t_{off}

The turn off time shall be stated by the manufacturer and measured according to 8.5.

7.2.1.10 Excess Gain, Photoelectric Proximity Switch

The excess gain and the measuring method shall be stated by the manufacturer.

7.2.1.11 Rated (Nominal) Operational Current I_e

The rated operational current I_e shall be:

50 mA DC or 200 mA AC rms

and verified according to the requirements found in 7.2.2 Temperature rise. Greater values may be agreed upon between manufacturer and user.

7.2.1.12 Minimum Operational Current I_m

The minimum operational current I_m verified according to 8.3.3.2.2 shall be:

for 2 terminals $I_m \leq 5$ mA DC or AC rms,

for 3 or 4 terminals $I_m \leq 1$ mA

For PLC compatibility requirements see Annex C.

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7.2.1.13 OFF-State Current I_r

The maximum current (I_r) which flows through the load circuit of a proximity switch in the OFF-state verified according to 8.3.3.2.3 shall be:

or 2 terminals	$I_r \leq$ 1.5 mA DC or
	$I_r \leq$ 3 mA AC rms
for 3 or 4 terminals	$I_r \leq$ 0.5 mA

For PLC compatibility requirements see Annex C.

7.2.1.14 Switching Element Operation

The switching element operation shall be independent action and shall be verified according to 8.3.3.2.4.

7.2.1.15 Voltage Drop U_d

The true rms voltage drop measured according to 8.3.3.2.5 shall be:

for 2 terminals	$U_d \leq$ 8 volts (DC applications)
	$U_d \leq$ 10 volts (AC applications)
for 3 or 4 terminals	$U_d \leq$ 3.5 volts

For PLC compatibility requirements see Annex C.

7.2.2 Temperature Rise

ICS 5, Part 1 and ICS 1 apply with the following additions.

The temperature rise limit for proximity switches is 50°C. This temperature rise applies for the exterior of enclosure, and for the terminals. The temperature rise shall be verified in accordance with 8.3.3.3.

7.2.3 Dielectric Properties

Where the manufacturer has declared a value for the rated impulse withstand voltage U_{imp} (see 4.3.1.3), the dielectric properties shall be verified in accordance with the tests in Annex A of ICS 1 and 8.3.3.4.4.

Where the size of the proximity switch prevents the use of internal protective means the manufacturer shall specify the level of external protection necessary to achieve this requirement.

Where the manufacturer has not declared a value of U_{imp} the test for verifying dielectric properties shall be made in accordance with 8.3.3.4.1 – 8.3.3.4.3.

7.2.4 Ability To Make And Break

7.2.4.1 Making and breaking capacities under normal conditions

The switching elements shall be capable of making and breaking currents without failure under the conditions stated in Table 1-8-2 in ICS 5, Part 1, for the relevant utilization categories and the number of operations indicated, under the conditions specified in 8.3.3.5.

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.2.4.2 Making And Breaking Capacities Under Abnormal Conditions

The switching elements shall be capable of making and breaking currents without failure under the conditions stated in Table 1-8-3 in ICS 5, Part 1, for the relevant utilization categories and the number of operations under the conditions specified in 8.3.3.5.

7.2.5 Conditional Short-Circuit Current

The switching element shall withstand the stresses resulting from short-circuit currents under conditions specified in 8.3.4.

7.2.6 Electromagnetic Compatibility (EMC)

The operating characteristics of the proximity switch shall be maintained at the levels of electromagnetic compatibility (EMC) specified below. For test procedures see 8.6.

7.2.6.1 Radiated Electromagnetic Field Withstandability

In accordance with ICS 11-3. The minimum test field strength shall be 3 V/m ±10% for the frequency band of 27 MHz to 1000 MHz.

7.2.6.2 Electrostatic Discharge (ESD) Withstandability

In accordance with ICS 11-2 and 8.6.2.

The test voltage shall be applied by the contact discharge method to proximity devices with metallic enclosures.

The minimum test voltage shall be 4 kV.

The test voltage shall be applied by the air gap discharge method to proximity devices with nonmetallic enclosures.

The minimum test voltage shall be 8 kV.

7.2.6.3 Fast Transient Withstandability

In accordance with ICS 11-4. The minimum test voltage shall be 1 kV ±10%.

7.2.6.4 Emission Requirements

Description of the tests, test methods and setups are given in the standards listed in CISPR 11. Values of emission limits for proximity switches installed in normal service conditions are given in Table 4-8-2.

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Table 4-7-2
Emission Limits For Proximity Switches

Port	Frequency range, MHz	Limits
Enclosure	30 to 230	40 dB (mV/m) quasi peak, measured at 10 meter distance
	230 to 1000	47 dB (mV/m) quasi peak, measured at 10 meter distance
AC mains	0.15 to 0.50	79 dB (mV) quasi peak 66 dB (mV) average
	0.50 to 30	73 dB (mV) quasi peak 60 dB (mV) average

7.2.7 Shock And Vibration

7.2.7.1 Shock

In accordance with ICS 1 with the following conditions:

Six shocks applied in each direction along three mutually perpendicular axes (six separate tests):

Pulse shape: half-sine
Peak acceleration: 30 g
Duration of the pulse: 11 ms

7.2.7.2 Vibration

In accordance with ICS 1 with the following conditions, along three mutually perpendicular axes:

Frequency range: 10 Hz to 55 Hz
Amplitude: 1 mm for inductive, magnetic, capacitive and ultrasonic proximity switches
0.5 mm for photoelectric proximity switches
Sweep cycle duration: 5 min
Duration of endurance at resonant frequency or at 55 Hz: 30 min in each of the three axes (90 min in all).

7.2.7.3 Results to be obtained

After the test, the operating characteristics shall remain as given in Clause 4.

8 TESTS

8.1 Kinds Of Tests

8.1.1 General

ICS 5 Part 1 and ICS 1 apply.

8.1.2 Type tests

Type tests are intended to verify compliance with this standard. This comprises the verification of:

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a. Temperature rise (8.3.3.3).
b. Dielectric properties (8.3.3.4).
c. Making and breaking capacities (Clause 8 of ICS 5, Part 1).
d. Performance under short-circuit current (8.3.4).
e. Operating distances (8.4).
f. Standard frequency of operation (8.5).
g. Electromagnetic compatibility (8.6).
h. Shock (7.2.7.1).
i. Vibration (7.2.7.2).

Where a family of proximity switches are made according to the same principle and design, and using the same type of components, tests may be limited to a representative sample.

8.1.3 Routine Tests

Routine tests are the responsibility of the manufacturer and are usually limited to the mechanical inspection and verification of electrical operation. This may be supplemented by a dielectric test. When the dielectric test is performed as a routine test, it is carried out according to 8.3.3.4 and the test duration may be reduced to 1 second.

8.2 Compliance With Construction Requirements

Clause 7 of ICS 5, Part 1 applies.

8.3 Testing Procedures

3.1 Test Sequences

The tye and sequence of tests to be performed on five representative samples are as follows:

Sample No. 1

Test No. 1 - temperature rise (8.3.3.3).
Test No. 2 - mechanical properties of terminals (ICS 1).
Test No. 3 - dielectric properties (8.3.3.4).
Test No. 4 - visual inspection.

Sample No. 2

Test No. 1 - degree of protection (per NEMA Standard 250).
Test No. 2 - vibration (7.2.7.2).
Test No. 3 - standard frequency of operation (8.5).
Test No. 4 - operating distances (8.4).
Test No. 5 - dielectric properties (8.3.3.4).

Sample No. 3

Test No. 1 - degree of protection (per NEMA Standard 250).
Test No. 2 - shock (7.2.7.1).
Test No. 4 - standard frequency of operation (8.5).
Test No. 5 - dielectric properties (8.3.3.4).

Sample No. 4

Test No. 1 - making and breaking capacities (Clause 8 of ICS 5, Part 1).
Test No. 2 - dielectric properties (8.3.3.4).
Test No. 3 - operating distances (8.4).

Sample No. 5

Test No. 1 - electromagnetic compatibility (8.6).

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Test No. 2 - performance under short-circuit conditions (8.3.4).
Test No. 3 - dielectric properties (8.3.3.4).
Test No. 4 - operating distances (8.4).

There shall be no failure of any of the above tests.

More than one test sequence or all test sequences may be conducted on one sample at the request of the manufacturer. However, the test shall be conducted in the sequence given above for each sample.

Where a range of proximity switches are made according to the same principle and design, and using the same type of components, tests may be limited to a representative sample.

8.3.2 General Test Conditions

8.3.2.1 General Requirements

ICS 5 Part 1 applies unless otherwise specified with the following addition.

8.3.2.1.1 Standard Target For Inductive And Capacitive Proximity Switches

The standard target is square shape having a thickness of 1 mm and made of carbon steel and it shall be cold rolled.

The length (a) of the side of the square is equal to the diameter of the circle inscribed on the active surface of the sensing face, or three times the rated operating distance s_n, whichever is greater (Figure 4-9-1).

For a capacitive proximity switch, the standard target shall be connected to earth ground.

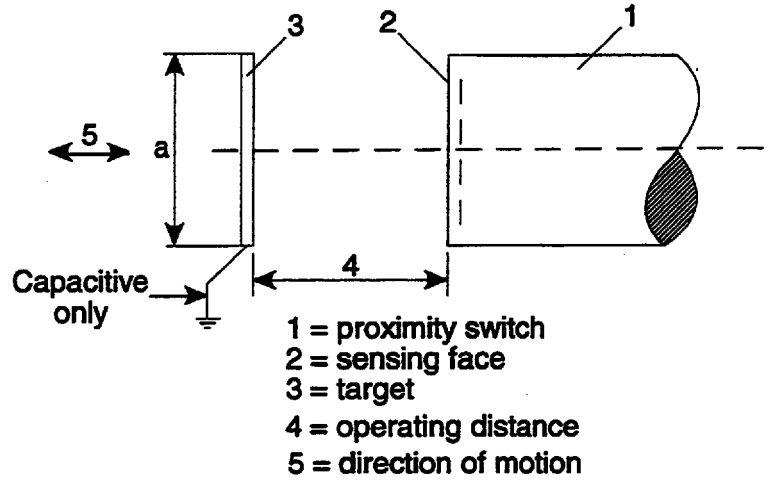


Figure 4-8-1
Method Of Measuring Operating Distance

8.3.2.1.2 Standard Target For Ultrasonic Proximity Switch

The standard target is square shape, having the thickness of 1 mm and made from metal with rolled finish. The dimensions for the target are given in Table 4-8-1.

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Table 4-8-1
Standard Target Sizes For Ultrasonic Proximity Switches

Sensing Range	Minimum Sensing Distance mm	Maximum Sensing Distance mm	Target size mm
A	60	300	10 x 10
B	300	800	20 x 20
C	300	1000	20 x 20
D	500	2000	100 x 100
E	800	6000	100 x 100

8.3.2.1.3 Standard Target For Photoelectric Proximity Switch

a) Retroreflective (Type R)

For the purpose of this test, the standard target is opaque, and equal to or larger than the size of the reflector specified by the manufacturer.

b) Through beam (Type T)

For the purpose of this test, the standard target is opaque, and equal to or larger than the size of the emitter or receiver optics, whichever is larger, as specified by the manufacturer.

c) Diffuse reflective (Type D)

1. 100 x 100 mm white paper with 90 percent reflectivity, up to 400 mm sensing distance, s_d
2. 200 x 200 mm white paper with 90 percent reflectivity, over 400 mm sensing distance, s_d

8.3.2.1.4 Standard Target For Magnetic Proximity Switch

a) Internal: 100 x 100 mm cold-rolled carbon steel with a thickness of 12 mm

b) External: as specified by the manufacturer.

8.3.2.2 Evaluation Of Test Result

The condition of the proximity switch after each test shall be compared to the pass/fail requirements described in each test procedure.

The proximity switch is deemed to have met the requirements of this standard if it meets the requirements of each test and/or test sequence as applicable.

8.3.3 Performance Under No Load, Normal Load And Abnormal Load Condition

8.3.3.1 Operation

ICS 5, Part 1 applies.

8.3.3.2 Operating Limits

Operational voltages are defined under 7.2.1.2.

8.3.3.2.1 Time delay before availability

(see 7.2.1.7)

The test is performed with the proximity switch connected to a test circuit shown in Figure 4-8-2. The standard target is placed in a position such that the switching element is in the ON-state. With rated

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operational voltage U_e, or with the minimum value of the rated operational voltage when it is given as a range, the load is adjusted to obtain the minimum operational current I_m.

The time delay before availability t_v and the duration of any false signal are measured by recording the signal across the load with an oscilloscope as the bounce-free switch is closed. Figure 4-8-3 shows typical oscillograms for a DC switching element. Figure 4-8-3a shows the oscillogram when the switching element is in ON-state and Figure 4-8-3b shows the oscillogram when the switching element is in OFF-state.

For inductive and capacitive proximity switches the standard target shall be positioned at either $^1/_3\ s_n$ or $3\ s_n$.

The measured time delay before availability, the time between t_3 and t_o in Figure 4-8-3 shall be according to 7.2.1.7. The duration of the false signal, if any, the time between t_2 and t_1 on Figures 4-8-3a and 4-8-3b, shall be according to 7.2.1.7.

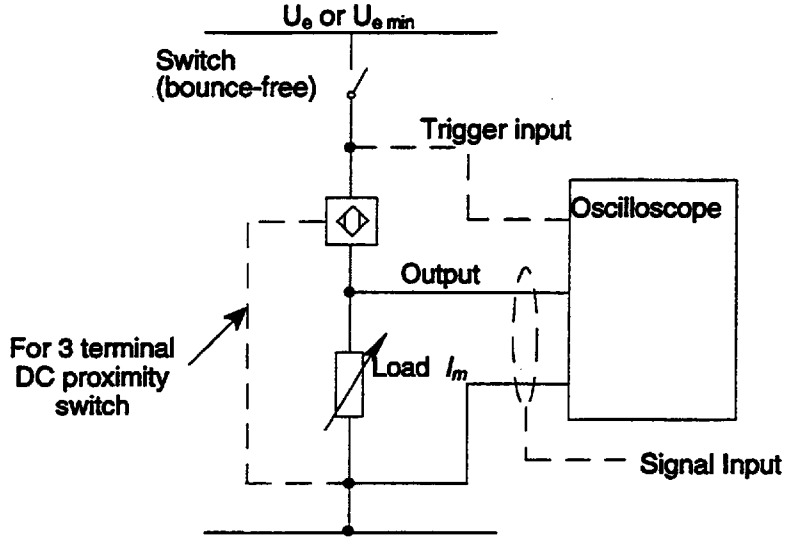
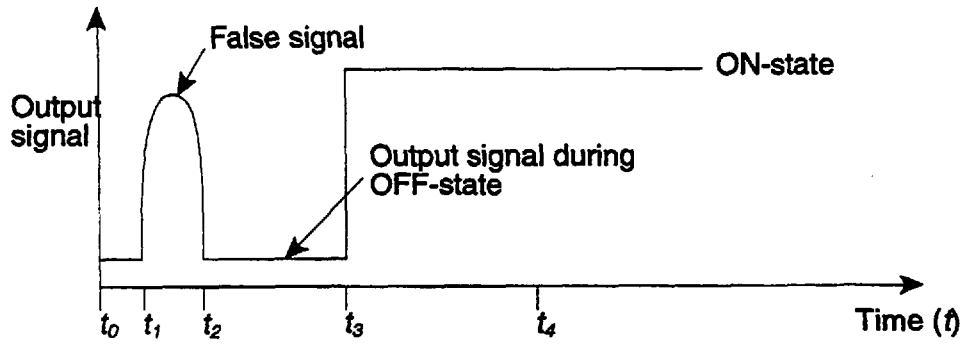
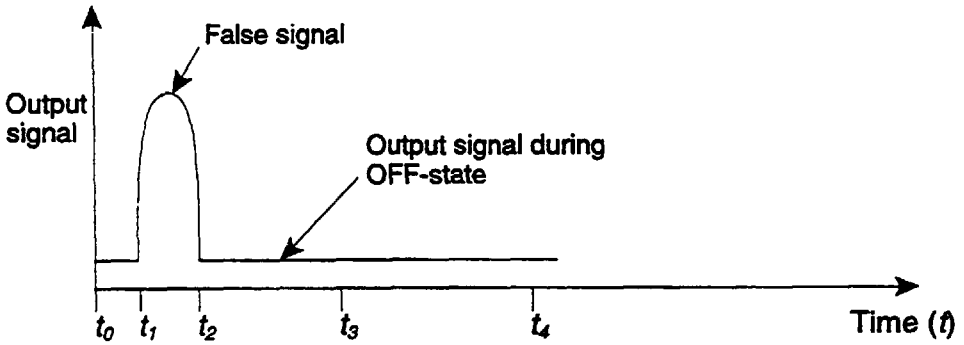


Figure 4-8-2
Test Circuit For The Verification Of Time Delay Before Availability

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(a) Switching element is in ON-state



(b) Switching element is in OFF-state

= supply is switched on
t_1 = beginning of false signal (if any)
t_2 = end of false signal (if any)
t_3 = end of time delay
t_4 = maximum time for delay (300 ms)

NOTES
1. The false signal (if any) may begin at t_0 ,which means that t_0 and t_1 are the same time marks.
2. In case of no false signal, the time mark t_3 can have any position between t_0 and t_4.
3. The wave-form of the false signal (if any) is not defined.

Figure 4-8-3
Signal Output Across Load In Figure 4-8-2

8.3.3.2.2 Minimum Operational Current I_m

(see 7.2.1.12)

The test is performed with the proximity switch connected to a test circuit shown in Figure 4-8-4.

The standard target is placed in a position such that the switching element is in the ON-state.

With supply voltage U_e and the switch S being open, the load R_1 is adjusted to obtain the current I_m. The measured value shall not exceed the value specified in 7.2.1.12.

The switching element shall not change state during the test.

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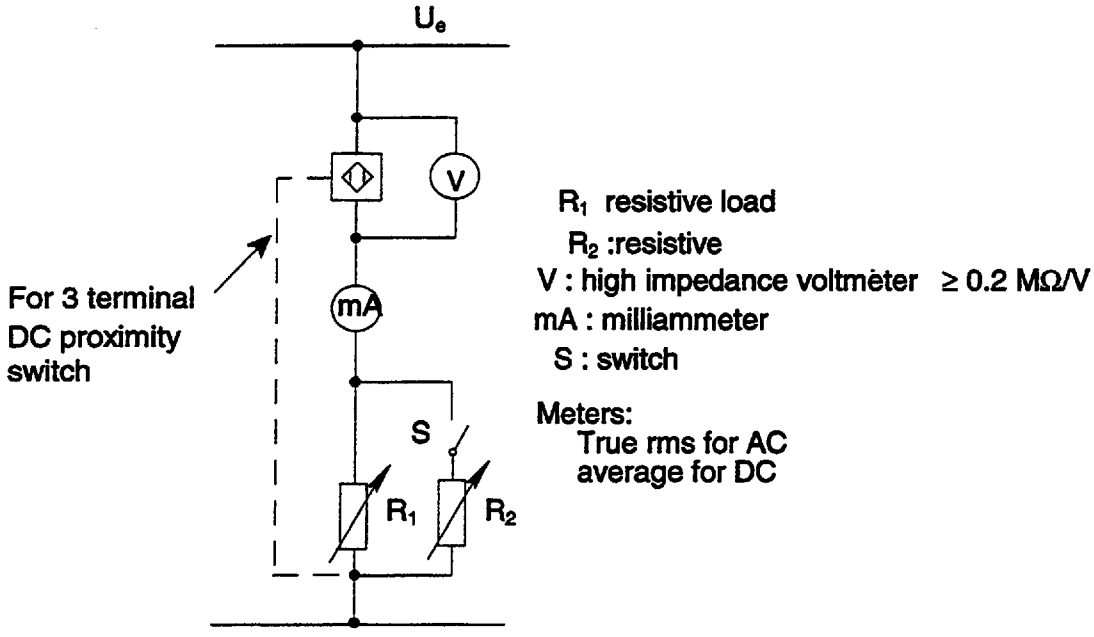


Figure 4-8-4
Test Circuit For The Verification Of Minimum Operational Current (8.3.3.2.2), OFF-State Current (8.3.3.2.3), Voltage Drop (8.3.3.2.5), And Independent Snap Action (8.3.3.2.4)

8.3.3.2.3 OFF-State Current I_r

(see 7.2.1.13)

With the circuit in Figure 4-8-4 and the switch S open, the standard target is then moved in a position such that the switching element is in the OFF-state.

The OFF-state current, I_r, shall be measured with supply voltage U_e +10 percent or with the maximum value of the supply voltage U_e where it is specified as a range. The I_r current shall not exceed the value specified in 7.2.1.13 over the operating temperature range per 6.1.1.

8.3.3.2.4 Independent (Snap) Action

(see 7.2.1.14)

Independent (snap) action shall be checked at maximum and minimum operating load currents at both maximum and minimum rated operating voltages. Resistive loads of appropriate value shall be used for each of the four tests.

These tests shall be carried out by moving the standard target from a position where the switching element is in the OFF-state to a position where the switching element is in the ON-state and observing the output on an oscilloscope. The switching element function shall be substantially independent from the velocity of the standard target and the output shall switch between the ON-state and the OFF-state without oscillating, or holding at any intermediate level.

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3.3.2.5 Voltage Drop U_d

(see 7.2.1.15)

The voltage drop is measured across the active outputs of the proximity switch when the switching element is in the ON-state over the rated temperature range. This measurement is performed with the circuit in Figure 4-8-4 in two cases:

a) The switch S closed. The load R_2 is adjusted to obtain the rated operational current I_e

b) The switch S open. The load R_1 is adjusted to obtain the minimum operational current I_m as in 8.3.3.2.2.

The voltage drop is measured with the supply voltage U_e

- at U_e +10 percent and U_e -15 percent,
- or U_{max} and U_{min}

The measured voltage drop shall not exceed the values specified in 7.2.1.15.

8.3.3.3 Temperature Rise

(see 7.2.2)

The proximity switch, installed in free air, is supplied with its rated operational voltage U_e (or the highest operational voltage of its voltage range), and connected to a load corresponding to its rated operational current I_e until the thermal equilibrium is reached.

The temperature rise, measured on the terminals when applicable, and on any point of the enclosure, shall not exceed 50°C.

The length of each conductor is 2 m +0.1 m, -0.0 m for integrally connected cable and 4 feet of wire er terminal, sized per rated operational current of device under test.

8.3.3.4 Dielectric Properties

(see 7.2.3)

The proximity switch shall be capable of withstanding the dielectric tests specified in 8.3.3.4.1 – 8.3.3.4.3 or in 8.3.3.4.4.

8.3.3.4.1 Application Of The Test Voltage

This test is to be carried out under circumstances approaching actual service conditions e.g. with conductors attached. The external surface of all insulating parts likely to be touched in service shall be made conducting by being closely covered by a metal foil.

The proximity switch shall be capable of withstanding the test voltage applied for 1 minute for a type test, and 1 second for routine test with the following conditions:

a. between live parts of the switching element and parts of the proximity switch intended to be earth grounded;

b. between live parts of the switching element and surfaces of the proximity switch likely to be touched in service, conducting or made conducting by metal foil;

c. between live parts belonging to electrically separated switching elements, if any;

d. for the 1 second test, a test voltage 20 percent greater than specified in Table 4-8-2 shall be applied.

8.3.3.4.2 Value Of The Test Voltage

The dielectric test voltage is applied according to 8.3.3.4.1. The test voltages are given in Table 4-8-2.

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8.3.3.4.3 Results To Be Obtained

As specified in Clause 8.4.9 of ICS 1.

8.3.3.4.4 Impulse Voltage Withstandability

In accordance with IEC 255-5.

NOTE: this test is not intended to verify withstandability against lightning effects.

The minimum test voltage shall be 1 kV ±10%. All exposed metal parts except terminals shall be grounded. The characteristics of the impulse generator are:

impulse:	1.2/50 µs;
source impedance:	500 Ω;
source energy:	0.5 joule.

The test is performed according to the following additional requirements.

a. The proximity switch is not powered during the test.

b. The impulse test shall be applied:
   1. between all terminals connected together and earth ground;
   2. between terminals intended to be connected to power supply;
   3. between each output terminal and each terminal intended to be connected to power supply.

c. Three positive and three negative impulses shall be applied between each two points at intervals of not less than 5 seconds.

Note: The impulse voltage withstandability test is designed as a type test.

Table 4-8-2
Dielectric Test Voltages

Rated insulation voltage	Dielectric test voltage	
	AC (50/60 Hz)	DC
Equipment rated not more than 50 VAC or 70.7 VDC	500 Volts	707 Volts
Equipment rated greater than 50 V AC or 70.7 V DC	1000 + (2 x rated voltage) Volts	1414 + (2.828 x rated voltage) Volts

8.3.3.5 Making And Breaking Capacities

(see 7.2.4)

Tests for verification of making and breaking capacities shall be made according to Clause 8 of ICS 5, Part 1.

8.3.3.5.1 Test Circuits

The load impedance shall be placed on the load side of the device as shown In Figure 4-8-5. The circuit voltage with the test current flowing shall not be less than U_e.

8.3.3.5.2 Making And Breaking Capacities Under Normal Conditions

The load circuitry shall be adjusted to give the values shown in Table 1-8-2 of ICS 5, Part 1.

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.3.3.5.3 Making And Breaking Capacities Under Abnormal Conditions

The load circuitry shall be adjusted to give the values shown in Table 1-8-3 of ICS 5, Part 1.

8.3.3.5.4 Results To Be Obtained

After the test, the effective operating distance of the proximity switch shall be measured and remain within the limits given in 7.2.1.3.1.

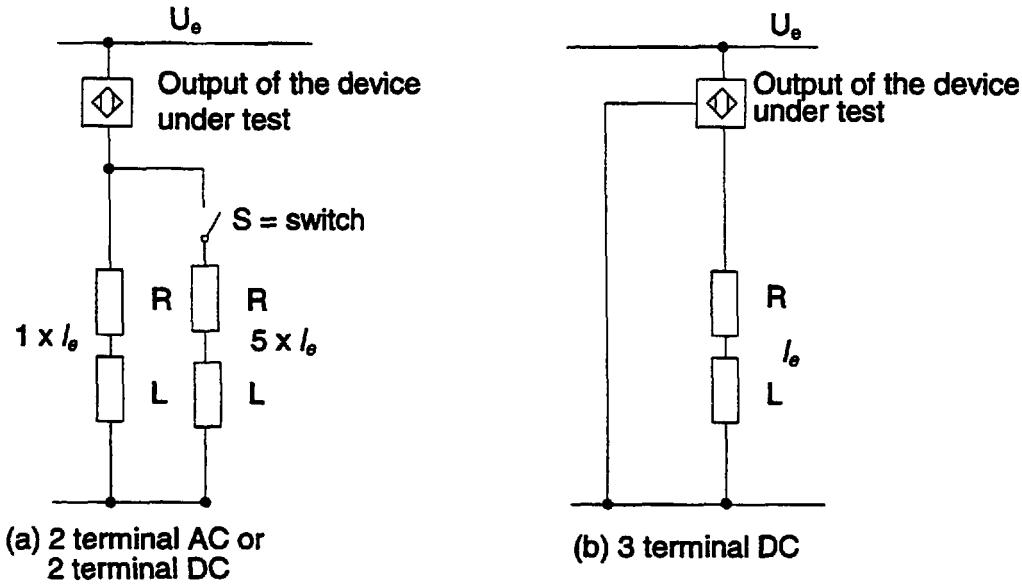


Figure 4-8-5
Test Circuit For The Verification Of Making And Breaking Capability

8.3.4 Performance Under Short-Circuit Current Conditions

(see 8.2.5)

8.3.4.1 Test Circuit And Test Procedure

The proximity switch, PS, in new condition shall be mounted as in service, in free air, and connected to the test circuit with the same size wire as used in service and with a test cable length of one meter, see Figure 4-8-6.

The short-circuit protective device, SCPD, shall be of the type and rating stated by the manufacturer. This SCPD shall be omitted if the proximity switch is integrally protected against short circuits.

The standard target is placed in a position such that the switching element is in the ON-state, R1 is selected so that the current flowing through the proximity switch is equal to its rated operational current. The supply S shall be adjusted to 100 A prospective short-circuit current. The SC switch, parallel with R1 load, is intended to cause the short circuit. The open circuit voltage shall be 1.1 times the rated operational voltage or the maximum value of the voltage range.

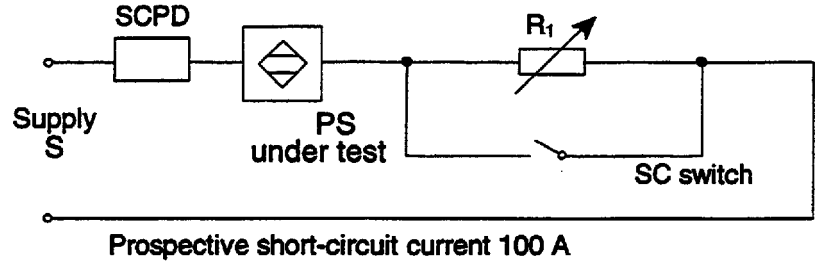
The test shall be performed three times by randomly closing the SC switch. The test current is maintained until the SCPD or the internal short-circuit protection in the proximity switch has operated. The

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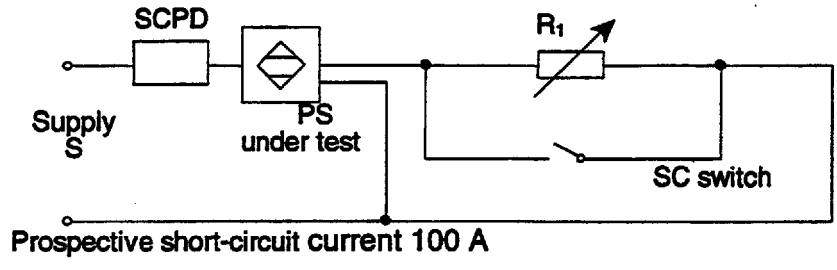
interval between each of the three tests shall be not less than 3 min. The actual time between tests shall be stated in the test report. After each test, the SCPD shall be replaced or reset.

8.3.4.2 Results To Be Obtained

After the test, the operating distance of the proximity switch shall be measured and remain within the limits given in 7.2.1.3.1.



(a) 2 terminal AC or 2 terminal DC



(b) 3 terminal DC

Figure 4-8-6
Short-Circuit Testing

8.4 Operating Distances

(see 7.2.1.3)

8.4.1 Inductive, Magnetic, Capacitive And Ultrasonic Proximity Switches

8.4.1.1 Test Conditions

A proximity switch in new condition is mounted according to the manufacturers instructions and the standard target is moved, not faster than 1 mm per second, towards and away from the sensing face of the proximity switch in an axial direction. The operating distances are measured as shown in Figure 4-4-1 and Figure 4-4-2.

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8.4.1.2 Effective Operating Distance s_r

The effective operating distance s_r is measured at the rated voltage or at any voltage within the voltage range and at 23°C ±5°C ambient air temperature. The measured value shall be within the limits given in 7.2.1.3.1.

8.4.1.3 Differential Travel H

The differential travel H is defined as a percentage of the effective operating distance s_r. The measurement is made at the ambient temperature of 23°C ±5°C at rated supply voltage. The standard target shall be moved towards the proximity switch within the s_r range and then be moved away from the proximity switch. The measured value shall be according to 7.2.1.5.

8.4.1.4 Usable Operating Distance s_u

Usable operating distance is measured over the –25°C to +70°C ambient temperature range with the supply voltage at 85 percent and 110 percent of its rated value (U_e), or at the limits of the range specified by the manufacturer (U_B). The standard target shall be moved towards the proximity switch. The measured value shall be within the limits given in 7.2.1.3.2.

8.4.1.5 Repeat Accuracy R

(see 7.2.1.4)

The repeat accuracy of the effective operating distance s_r is measured hourly over an eight hour period at an ambient temperature of between 23°C ±5°C at a relative humidity of any value in the range specified in 6.1.3.1 to a tolerance of ±5 percent and with a specified supply voltage. The standard target shall be moved axially towards the proximity switch. The measured value shall be within the limits given in 7.2.1.4.

8.4.2 Photoelectric Proximity Switches

(see 7.2.1.3.4)

8.4.2.1 Testing Of The Sensing Range s_d

This test is performed at rated voltage or at any voltage within the voltage range with new photoelectric proximity switches, except when specified as verification after another test, in clean air conditions, at any ambient temperature of 23°C ±5°C, both in darkness (0 lux) and at an ambient light of 5000 lux.

The ambient light source shall be:

a. 24 x 36 (35 mm) slide projector, with glass condensing lens of focal length 80 mm, with anti-caloric (heat) filter removed, with tungsten halogen lamp, color temperature between 3000 K and 3200 K (by varying supply voltage) and delivering 5000 lux measured with luxmeter and obtained by varying the distance between the light source and the luxmeter.

or

b. Xenon lamp delivering 5000 lux measured with luxmeter and obtained by varying the distance between the light source and the luxmeter.

8.4.2.2 Through Beam (Type T)

The receiver is moved, not faster than 1 mm per second, in an axial direction towards the emitter, and the maximum and minimum operating distances are measured:

a. without ambient light (0 lux);
b. with ambient light (5000 lux).

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The light source is positioned at an angle of 5° ±1° to the reference axis and is aimed at the receiver (see Figure 4-7-2a, through beam (type T)).

8.4.2.3 Retroreflective (Type R)

The reflector, per 8.3.2.1.3(a), is moved, not faster than 1 mm per second, in an axial direction towards the photoelectric proximity switch, and the sensing range is measured:

a) without ambient light (0 lux);

b) with ambient light (5000 lux).

The light source is positioned at an angle of 5° ±1° to the reference axis and is aimed at the photoelectric proximity switch (see Figure 4-7-2b, Retroreflective (type R)).

8.4.2.4 Diffuse Reflective (Type D)

The standard target, as specified in 8.3.2.1.3(c), is moved, not faster than 1 mm per second, in an axial direction towards the photoelectric proximity switch, and the sensing distance is measured:

a) without ambient light (0 lux);

b) with ambient light (5000 lux).

The light source is positioned at an angle of 15° ±1° to the reference axis and is aimed at the photoelectric proximity switch (see Figure 4-7-2c, Diffuse reflective (type D)).

8.4.2.5 Results To Be Obtained

The sensing range s_d shall be as stated by the manufacturer (see 7.2.1.3.4).

8.5 Standard Frequency Of Operation

(see 7.2.1.6)

The standard frequency of operation f is determined from the following formula:

$$f = \frac{1}{t_1 + t_2}$$

where t_1 and t_2 represent the duration of the ON and OFF output signals.

8.5.1 Inductive, Magnetic And Capacitive Proximity Switches

Inductive and capacitive proximity switches as shown in Figure 4-8-8, the standard targets are fixed on the front (method 1) or sides (method 2) of teeth on a rotating disc, the spaces between the teeth being 2a, in such a manner that they can pass in front of the sensing face of the proximity switch at a distance equal to half of the rated operating distance.

Each standard target shall have the same dimensions as those specified in 8.3.2.1, or 8.3.2.1.4 for magnetic. The output signal of the proximity switch is measured with the speed of rotation of the disc increasing from zero. The standard targets of the rotating disc shall be connected to earth ground when capacitive proximity switches are tested.

An illustration of the output signal of proximity switches is given in Figure 4-8-9.

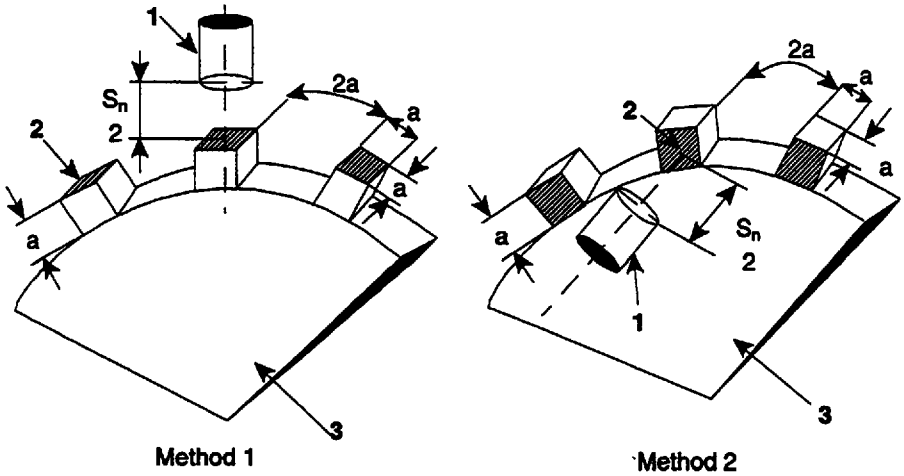
With the speed increasing, the durations t_1 and t_2 decrease.

NOTE - Where the proximity switch standard frequency of operation exceeds the limit of the measuring method described, the manufacturer shall state the method of measurement.

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For direct current proximity switches, the rated value of the operating frequency is obtained when t_1 or correspond to 50 µs, or when the characteristics of the output signal, in the "ON" or "OFF" states, reaches the values specified in Annex B.

For alternating current proximity switches, the rated value of the operating frequency is obtained when either t_1 or t_2 corresponds to one-half period of the supply frequency f_b.



NOTE: To avoid angular influence from one target to another, the disc shall be constructed to include at least 10 targets, if the rated operating distance (S_n) is less than 10 mm, or 6 targets for higher operating distances.

Figure 4-8-8
Methods For Measuring The Standard Frequency Of Operation For Inductive And Capacitive Proximity Switches

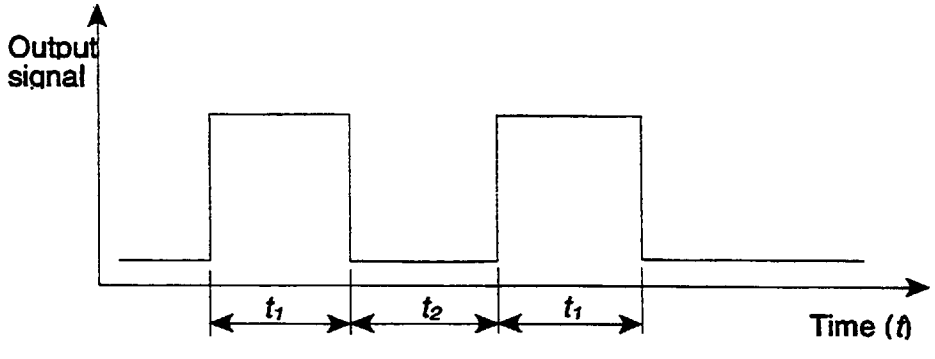


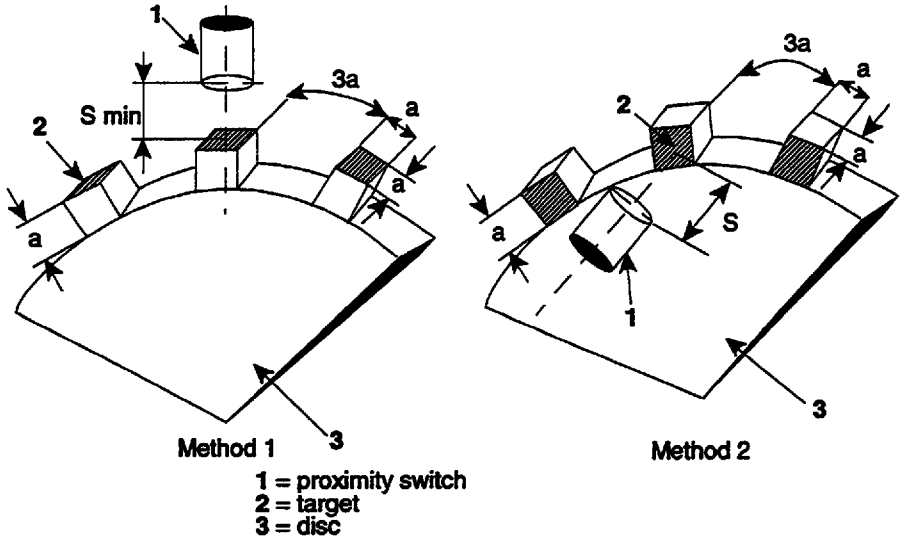
Figure 4-8-9
Output Signal Of Direct Current Proximity Switch During The Measurement Of The Standard Frequency Of Operation f

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8.5.2 Ultrasonic Proximity Switches

As shown in Figure 4-8-10 the standard targets are fixed on the front (method 1) or sides (method 2) of teeth on a rotating disc.

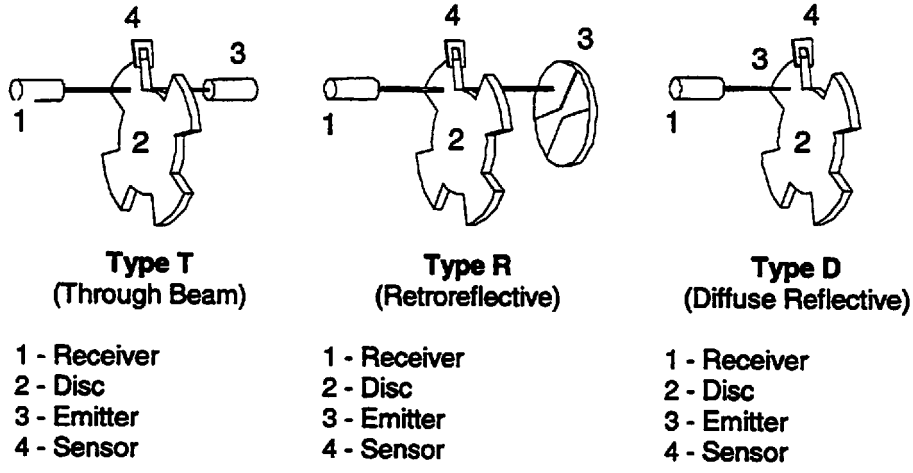
The spaces between the teeth being 3a in such a manner that they can pass in front of the sensing face at the minimum operating distance and the proximity switch shall be adjusted to this operating distance.



NOTES
1. To avoid angular influence from one target to another, the disc shall be constructed to include at least 10 targ
2. Method 2 is only applicable to narrow-beam angled proximity switches

Figure 4-8-10
Methods For Measuring The Standard Frequency Of Operation For Ultrasonic Proximity Switch

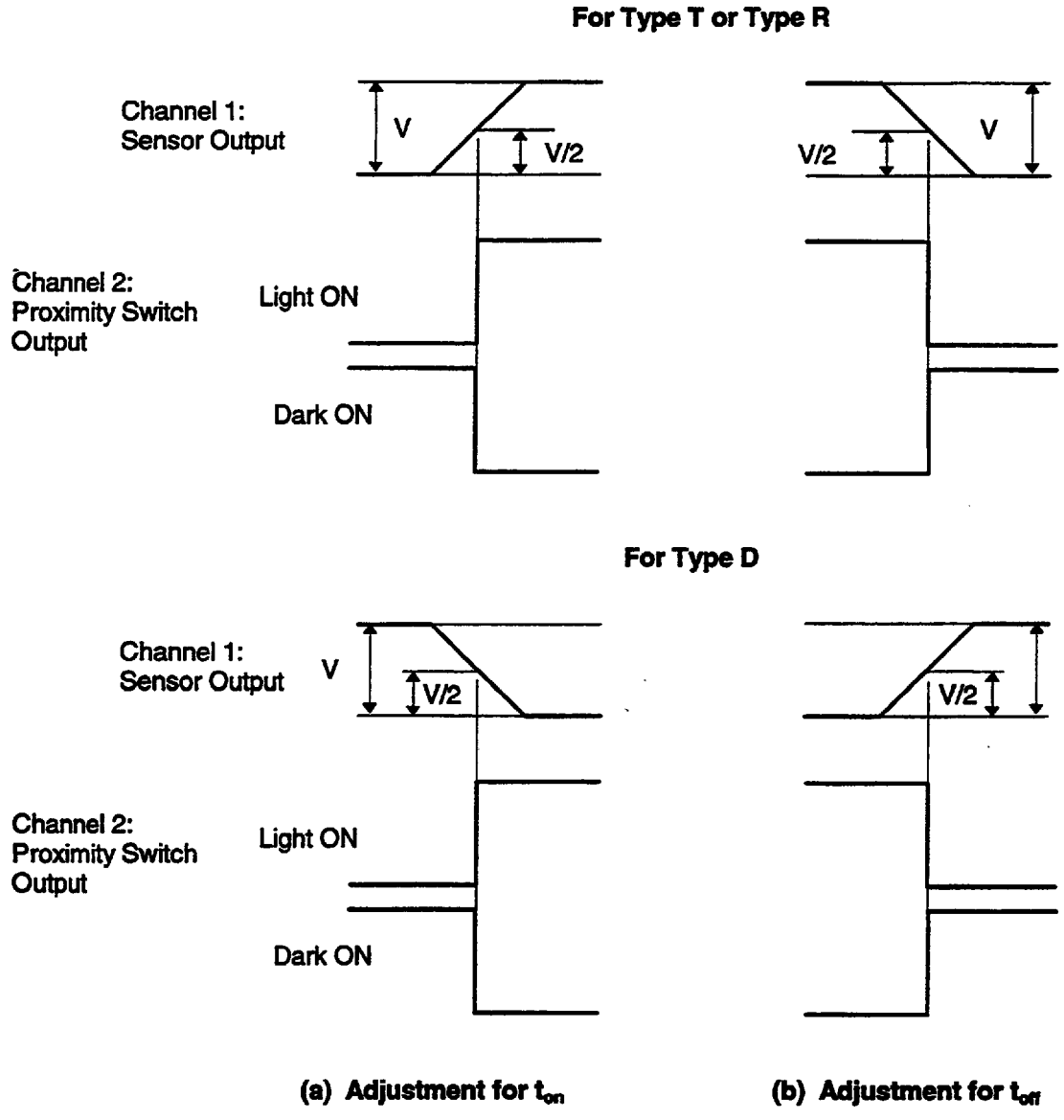
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Type T (Through Beam)	Type R (Retroreflective)	Type D (Diffuse Reflective)
1 - Receiver	1 - Receiver	1 - Receiver
2 - Disc	2 - Disc	2 - Disc
3 - Emitter	3 - Emitter	3 - Emitter
4 - Sensor	4 - Sensor	4 - Sensor

Figure 4-8-11
Measurement Means For Turn On t_{on} And Turn Off t_{off} Times

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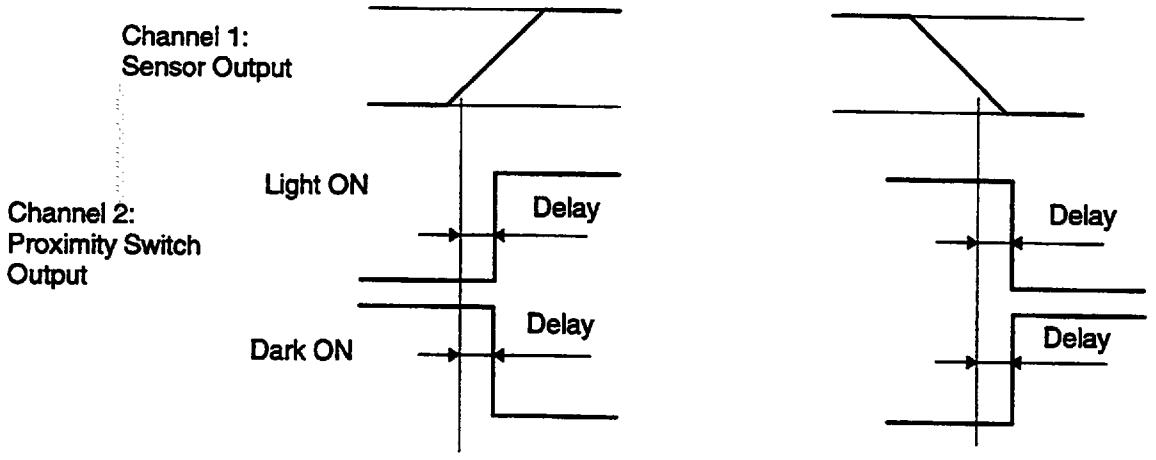


(a) Adjustment for t_{on} **(b) Adjustment for t_{off}**

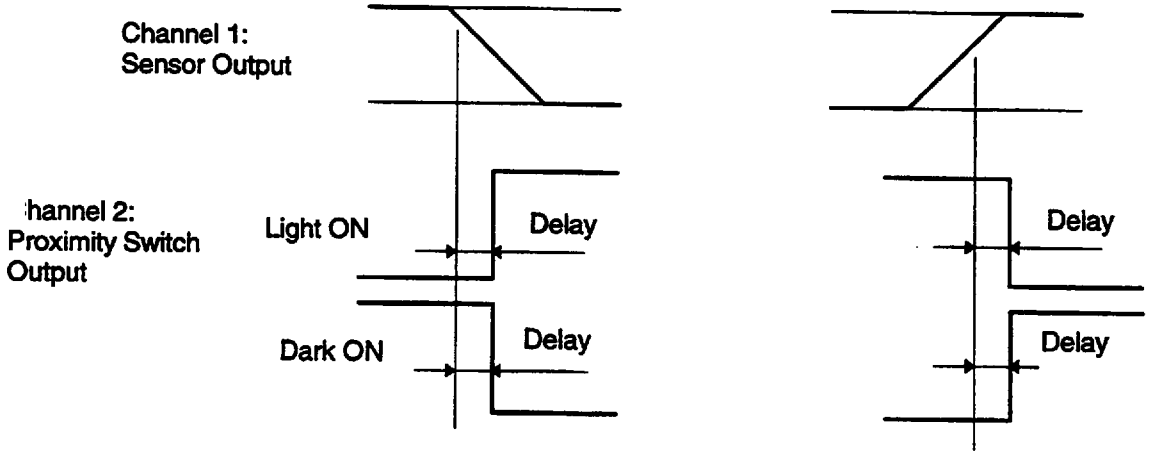
Figure 4-8-12
Adjustments for t_{on} and t_{off}

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For Type T or Type R



For Type D



(a) Delay t_{on} Measurement **(b) Delay t_{off} Measurement**

Figure 4-8-13
Measurements of Delay t_{on} and Delay t_{off}

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8.5.3 Photoelectric Proximity Switches

8.5.3.1 Measurements Means

As shown in Figure 4-8-11, a rotating disc where at least one tooth is fixed parallel to the sensing face of proximity switch at a distance equal to half of rated operating distance (½ s_n), so that the axis of the proximity switch passes near the center of the reflective tooth.

The teeth of the rotating disc shall be equal to or larger than the standard target specified in 8.3.2.1.3.

When the beam is not blocked by the disc, the effective operating distance measured shall be greater than 90 percent of the effective operating distance measured without the disc, at the same conditions.

To check if the beam is fully broken in the cut position, emitter (for Type T) or reflector (for Type R) is moved to immediate proximity of the disc plane. Output state shall not change.

An analog sensor shall be used to detect the tooth edge.

A recorder (e.g. a memory oscilloscope) can draw simultaneously curves delivered by the proximity switch and by the sensor. See Figure 4-8-12 and Figure 4-8-13.

8.5.3.2 Measurement Of Turn On Time (t_{on})

Excess gain is adjusted to 2 in detection position.

Sensor position is adjusted by moving slowly disc. The proximity switching element response after target enters in detection zone shall be when sensor response is 50 percent of maximum response. (See Figure 4-8-12a)

To measure t_{on}, disc speed is adjusted so that its period is of the order of 2/f (with f being the standard frequency of operation declared by the manufacturer.)

Record reading (see Figure 4-8-13a) can measure the delay until ON action. Turn on time t_{on} time is the maximum observed delay.

8.5.3.3 Measurement Of Turn Off Time t_{off}

Excess gain is adjusted to 0.5 in non-detection position.

Sensor position is adjusted by slowly moving disc. The proximity switching element response after target enters in detection zone shall be when sensor response is 50 percent of maximum response. (See Figure 4-8-12b)

To measure t_{off}, disc speed is adjusted so that its period is of the order of 2/f (with f being the standard frequency of operation declared by the manufacturer.)

Record reading (see Figure 4-8-13b) can measure the delay until ON action. Turn off time t_{off} time is the maximum observed delay.

8.5.3.4 Results To Be Obtained

The standard frequency of operation f as determined by the formula given in 8.5 shall no be less than that given by the manufacturer.

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8.6 Electromagnetic Compatibility

(see 7.2.6)

The following tests shall be performed under these common conditions:

The proximity switch mounted non-embedded, in free air is connected to a load corresponding to the rated operational current I_e and is supplied with its rated operational voltage (or the maximum voltage of its voltage range) U_e.

The connecting leads shall be 2 m +0.1 m, –0.0 m.

The test shall be performed:

a. with the standard target set at a position such that the switching element is in OFF-state;
b. with the standard target set at a position such that the switching element is in ON-state.

For inductive and capacitive proximity switches, the standard target shall be positioned at $^1/_3\ s_n$ or 3 s_n.

For the tests of 8.6.3 and 8.6.4 the following mounting conditions apply:

Proximity switches with metallic enclosures shall be mounted nonembedded on a grounded metal plate.

Proximity switches with nonmetallic enclosures shall first be closely covered by a metal foil, with the exception of the sensing face and free zone, and then mounted nonembedded on a grounded plate.

Based on first results, the testing laboratory may be able to limit the tested frequency range for radiation, conduction or electromagnetic field tests for a family of proximity switches.

During the test the state of the switching element shall not change for more than 1 millisecond.

8.6.1 Electromagnetic Field Withstandability

The test is performed according to ICS 11-3, and to 7.2.6.1.

8.6.2 Electrostatic Discharge Withstandability

The test is performed according to ICS 11-2, and to 7.2.6.2.

8.6.3 Fast Transient Withstandability

The test is performed according to ICS 11-4, and to 7.2.6.3, with all the connecting leads placed in the capacitive coupling clamp.

8.6.4 Emission Requirements

(see 7.6.5)

The test is performed according to CISPR 11.

The measurement shall be made in the operating mode including grounding conditions producing the highest emission in the frequency band being investigated which is consistent with normal applications.

Each measurement shall be performed in defined and reproducible conditions.

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9 APPLICATION

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Part 5
PUSHBUTTONS, SELECTOR SWITCHES, INDICATING LIGHTS AND PUSHBUTTON STATIONS

1 GENERAL

1.1 Scope

The standards in this part apply to indicating lights, pushbuttons, selector switches and related manually operated devices, as well as enclosed pushbutton stations used in control circuits of industrial control apparatus.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and 5, Part 1 apply to this part unless otherwise stated.

2 DEFINITIONS

For the purposes of this part the following definitions apply.

2.1 General Definitions

master switch: A switch which dominates the operation of contacts, relays, or other remotely operated devices.

2.2 Pushbutton Definitions

guarded pushbutton: A pushbutton so constructed that when properly mounted, the chance of inadvertent operation will be minimal. Recognized constructions are listed below.

a. Recessed pushbutton-A pushbutton where the actuating surface is below the surrounding surface in its initial and operated positions

b. Shrouded pushbutton-A pushbutton where the relationship between the guard and the actuating surface is specified by the manufacturer

c. Shielded pushbutton-A pushbutton which requires some movement to operate which is essentially perpendicular to the movement required to enter the shield

d. Covered pushbutton-A pushbutton having an automatically returnable cover which must be displaced prior to operating the pushbutton

e. Lockable pushbutton-A pushbutton which includes provision for locking in specified positionspushbutton: A switch having a manually operable plunger, rocker or button for actuating the switch.

pushbutton: A switch having a manually operable plunger, rocker or button for actuating the switch.

3 CLASSIFICATION

3.1 Standard-Duty Pushbutton Stations

Standard-duty pushbutton stations shall consist of pushbuttons or selector switches, or both, rated in accordance with 4.1.2 or indicating lights in accordance with 4.2 or both, mounted in a suitable enclosure.

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3.2 Heavy-Duty Pushbutton Stations

Heavy-duty pushbutton stations shall consist of pushbuttons or selector switches, or both, rated in accordance with 4.1.3 or indicating lights in accordance with 4.2, or both, mounted in a suitable enclosure.

4 CHARACTERISTICS AND RATINGS

4.1 Contact Ratings

4.1.1 Contact Ratings

The contact ratings of manually-operated pushbuttons and selector switches used in control circuits shall be in accordance with Clause 4 of Part 1.

4.1.2 Standard-Duty Pushbuttons and Selector Switches

Standard-duty pushbuttons and selector switches shall have contact rating designations of B600, B300, B150, P600, P300 or P150 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.

4.1.3 Heavy-Duty Pushbuttons and Selector Switches

Heavy-duty pushbuttons and selector switches shall have contact rating designations of A600, A300, A150, N600, N300 or N150 as shown in Table 1-4-1 for AC and Table 1-4-2 for DC.

4.2 Indicating Light Ratings

Indicating lights in pushbutton stations shall have any single voltage rating shown in Table 5-4-1.

Table 5-4-1
Indicating Light Voltage Ratings

Standard Duty		Heavy Duty	
AC, 60 Hertz	DC	AC, 60 Hertz	DC
120	120	6	6
240	240	12	12
		24	24
		120	120
		240	240
		480	
		600	

NOTE—The voltage impressed on the lamp bulb may be less than that shown in the table depending on the design details

4.3 Selector Switch Characteristics

Standard-duty selector switches shall have either two or three positions. Heavy-duty selector switches shall have two, three or more positions.

5 PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION

See NEMA Standards Publication ICS 1.3 for preventative maintenance instructions.

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6 SERVICE AND STORAGE CONDITIONS

See ICS 1, Clause 6 for standard service and storage conditions.

7 CONSTRUCTION

7.1 Color Coding of Pushbuttons

The color of those pushbuttons which perform a Stop function shall be red.

7.2 Direction of Operation of Selector Switches

7.2.1 Rotary Selector Switches

Where a rotary selector switch is mounted in a pushbutton station or in the cover of an AC magnetic nonreversing controller, the direction of rotation shall be such that the "hand" function is obtained in the counterclockwise direction of motion and the "automatic" function is obtained in the clockwise direction of motion.

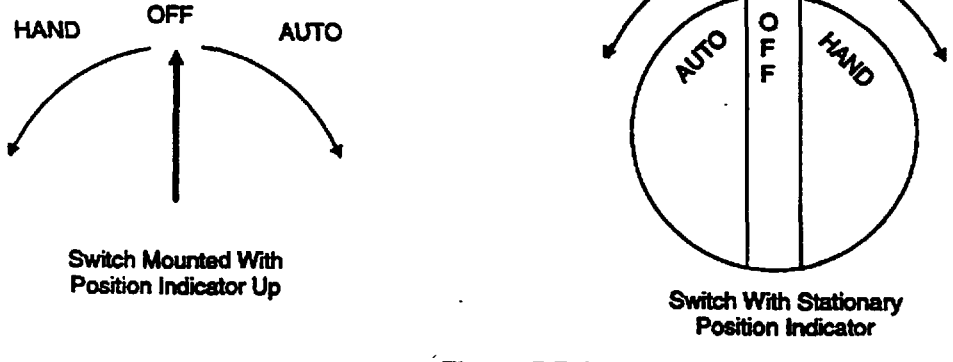


Figure 5-7-1
Rotary Selector Switch Operation

7.2.2 Straight-Line Motion Selector Switches

Where a selector switch having a lever with straight-line motion is mounted in a pushbutton station or in the cover of an AC magnetic nonreversing controller, the direction of motion shall be such that the "hand" function is obtained when the lever is moved to the left or moved downward and the "automatic" function is obtained when the lever is moved to the right or moved upward. See Figure 5-7-2.

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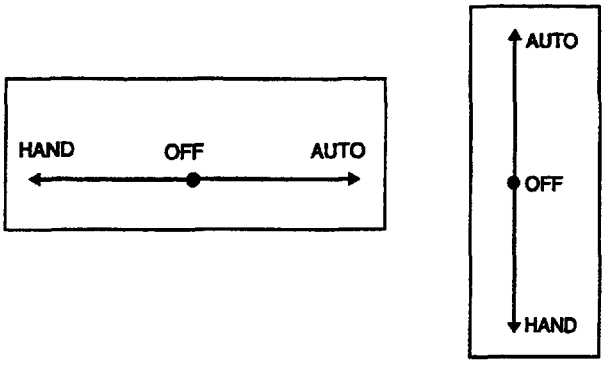


Figure 5-7-2
Lever Selector Switch Operation

7.3 Legends for Pushbutton Stations

Tables 5-7-1 and 5-7-2 show legends for standard-duty and heavy-duty pushbutton stations.

Table 5-7-1
Standard-Duty Pushbutton Station Legends

One-Button	Two-Button	Three-Button
Start	Start-Stop	Forward-Reverse-Stop
Stop	Forward-Reverse	Open-Close-Stop
	Open-Close	Up-Down-Stop
	Up-Down	Fast-Slow-Stop

Table 5-7-2
Heavy-Duty Pushbutton Station Legends

One-Button	Two-Button	Three-Button
Start	Start-Stop	Start-Job-Stop
Stop	Run-Stop	Run-Jog-Stop
Jog	Forward-Reverse	Forward-Reverse-Stop
Reset	Fast-Slow	Open-Close-Stop
	Open-Close	Fast-Slow-Stop
	Up-Down	Up-Down-Stop

7.4 Arrangement of Elements in Pushbutton Stations

7.4.1 Stop Button Location

On all single-row pushbutton stations, the "stop" button shall be located below or to the right of all other associated buttons, indicating lights and selector switches.

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.4.2 Arrangement of Pushbutton Stations for Multispeed Motor Controllers

Pushbutton stations used with multispeed motors shall be arranged as follows:

a. here mounted vertically, the lowest button shall be the stop button.The lowest-speed button shall be above the "stop" button, followed by those for consecutively higher speeds.
b. here mounted horizontally, the right-hand button shall be the "stop" button.The lowest-speed button shall be to the left of the "stop" button, followed by those for consecutively higher speeds.

8 PERFORMANCE REQUIREMENTS AND TESTS

8.1 Contact Performance

The contacts of pushbuttons and selector switches, when new, shall:

a. Not exceed the temperature rise given in ICS 1, Clause 8 when carrying continuous thermal test current.
b. Be capable of passing the overload, endurance and emergency condition tests described in Part 1.

9 APPLICATION

9.1 Contact Life

9.1.1 General

Because of the endless variety of application conditions in terms of electrical loads, duty cycles, voltage fluctuations, mechanical vibration, environmental conditions, etc., contact life is not specified in this NEMA Standards Publication. Therefore, manufacturer's recommendations should be obtained regarding specific applications.

9.1.2 Long Cycle Life

The make and break ratings and test values shown in Table 1-4-1 for alternating current and Table 1-4-2 for direct current shall not be used as application ratings where the total number of operations is expected to substantially exceed the number specified in the test conditions described in Part 1.

9.1.3 Solenoid Control Circuits

When the load is an alternating-current electromagnetically operated mechanical device whose coil current may be interrupted occasionally before completion of its stroke, such as in jogging, the break current of the load shall be considered to be 50 percent of the make current of the load. The load limitations given below include provision for this situation.

9.2 Overlapping Contacts

Because of manufacturing tolerances and the various characteristics of electrical loads, the normally-open and normally-closed contacts of a pushbutton may or may not be conducting current simultaneously during operation. If such overlap or nonoverlap is essential, the manufacturer should be consulted.

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Part 6
MECHANICAL CONTROL-CIRCUIT DEVICES WITH NORMALLY-CLOSED CONTACTS HAVING DIRECT-OPENING ACTION

1 GENERAL

1.1 Scope

This part covers control-circuit devices having normally-closed (break) contacts with direct-opening action, and specifies requirements and tests to be performed on such devices. Products that may include contacts with direct-opening action are described in Parts 3 and 5 of this standard.

1.2 Normative References

The definitions and standards of NEMA Standards Publication Nos. ICS 1, and Part 1 apply to this part unless otherwise stated.

2 DEFINITIONS

direct-opening action (of a contact element): The achievement of contact separation as the result of direct mechanical action.

direct-opening action device: Control-circuit devices having normally-closed contacts with direct-opening action.

direct-opening action travel: The minimum travel of the actuator from its free position to the position where the direct-opening action is completed.

direct-opening action force or torque: Actuation force, or actuating torque for a rotary control switch, applied to the actuator for the direct-opening action.

minimum direct-opening action force or torque: The minimum force or torque required to achieve direct-opening action operation of all normally-closed contacts.

3 CLASSIFICATION

There are no classifications unique to this part. Refer to ICS 5, Part 1.

4 CHARACTERISTICS AND RATINGS

4.1 Contact Ratings

4.1.1 AC Ratings

Direct-opening action control-circuit switch contacts shall be rated not less than C300.

4.1.2 DC Ratings

Additional DC contact ratings may be specified by the manufacturer.

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5 PRODUCT MARKING, INSTALLATION AND MAINTENANCE INFORMATION

5.1 Markings on the Device

Markings on mechanical control-circuit devices having direct-opening action contacts shall be in accordance with ICS 5 Part 1, and ICS 1 and shall be marked on the outside with the symbol as shown in Figure 6-5-1.

It is recommended that the direct-opening action contact symbol be used in electrical diagrams as shown in Figure 6-5-2.

5.2 Additional Information

The following information shall appear on the device or in documents provided by the manufacturer:

a. Direct-opening action travel.
b. Pretravel required for normal contact operation, where it is different from direct-opening action travel.
c. Minimum direct-opening action force or torque.
d. Total travel.
e. Minimum and maximum speed of actuation where applicable.
f. Maximum frequency of actuation.
g. The rating and type of short-circuit protective device (SCPD) to be used.

The minimum direct-opening action travel may be marked on the control switch.

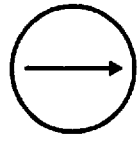


Figure 6-5-1
Device Marking For Direct-Opening Contacts



Figure 6-5-2
Electrical Diagram Symbol For Direct Opening Contacts

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6 SERVICE AND STORAGE CONDITIONS

There are no specific Service and Storage Conditions specified in this Part. See ICS 5, Part 1 and ICS 1.

7 CONSTRUCTION

7.1 Multiple Contacts

All normally-closed contacts in a direct-opening action device shall be of the direct-opening action type.

7.2 Contact Element Types

Control-circuit devices with direct-opening action may have snap action (independent) or slow make/slow break (dependent) action mechanisms.

8 PERFORMANCE AND TESTS

In addition to verification of the performance requirements in Clause 8 of Part 1, devicies having contacts with direct-opening action shall meet the following performance requirements:

a. Mechanical operation at temperature extremes (limit switches only) (8.2)
b. Robustness of direct-opening action (8.3)
c. Conditional short-circuit test (8.4)

After each of these tests the device will be subjected to verification of direct-opening action of 8.1.

8.1 Verification Of Direct-Opening Action

When the control switch is in the position corresponding to the direct-opening action travel as specified in 4.2(a), the contact gap shall withstand a 1.2/50 µs impulse voltage of 2500 volts as described in Clause 8.4.10 of ICS 1.

Direct-opening action of contacts is achieved by the application of the minimum direct-opening action force, stated by the manufacturer in 5.2(c), to the actuator through the direct-opening action travel.

After this test, the movable contact(s) and the actuating system may be deformed, but the contact gap shall withstand an impulse test voltage of 2500 volts.

8.2 Mechanical Operation Of Limit Switches With Direct-Opening Action Contacts At Temperature Extremes

The contacts of limit switches with direct-opening action contacts, under normal operating conditions, shall open at temperatures between –25°C and 70°C.

The limit switch with direct opening contacts shall be kept at 70°C for eight hours. After that, at the same temperature, the maximum rated current shall be applied to the closed contacts for 10 minutes. The contacts shall be operated 10 times by applying the minimum direct acting force or torque as stated in 5.2(c).

After the ten operations, the opening of contacts shall be verified as described in 8.1.

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The limit switch with direct opening contacts shall then be kept at –25°C for eight hours. Without applying a current, the contacts shall be operated 10 times by applying the minimum direct acting force or torque as stated in 5.2(c).

After the ten operations, the opening of contacts shall be verified as described in 8.1.

8.3 Robustness Of Direct-Opening Action

Contacts having direct-opening action, under normal operating conditions, shall be sufficiently robust that they will open when the contacts are loaded with an additional 10 N (2.25 lb) force opposing the opening of the contacts.

The contact(s) having direct-opening action shall be loaded with a force F_1 of 10 N (see figure 6-8-1). The minimum direct-opening action force or torque F_2, stated by the manufacturer (see 5.2(c)), shall be applied to the actuator through the direct-opening action travel.

Opening of contacts shall be verified as described in 8.1.

8.4 Conditional Short-Circuit Test

8.4.1 General Conditions For Short-Circuit Test

The switching element shall be in a new and clean condition, mounted as in service.

8.4.2 Test procedure

The switching element may be operated several times before the test, at no load or at any current not exceeding the rated current. The current shall be made by the direct opening contact element and the test consists of making the current three times by the same contact element. The test current is applied until the short-circuit protective device (SCPD) operates. After each test, the SCPD shall be replaced or reset.

The interval of rest between each of the three test shots shall be not less than 3 minutes.

8.4.3 Test Circuit And Test Quantities

The switching element shall be connected in series with the SCPD of the type and rating stated by the manufacturer (see 5.2(g)).

The load shall consist of an air-core reactor in series with a resistor. The load should be adjusted to provide a prospective current of 1000 amperes and a power factor of between 0.5 and 0.7 at the rated operational voltage. Shunting resistance shall not be used in the test circuit. The open circuit voltage shall be 110 percent of the maximum rated operational voltage of the switching element.

The switching element shall be connected in the circuit using a conductor length of one meter on each side (line and load) of the device under test. The conductor size shall correspond to the operational current of the switching element.

All the elements in the circuit shall be isolated (including the power supply L1, L2). The metal housing of the device under test or the metallic plate for a non-metallic enclosure shall be connected to L2 with a one ampere, non-time delay fuse.

After the test, opening of contacts shall be verified as described in 8.1 and the one ampere fuse shall not have opened.

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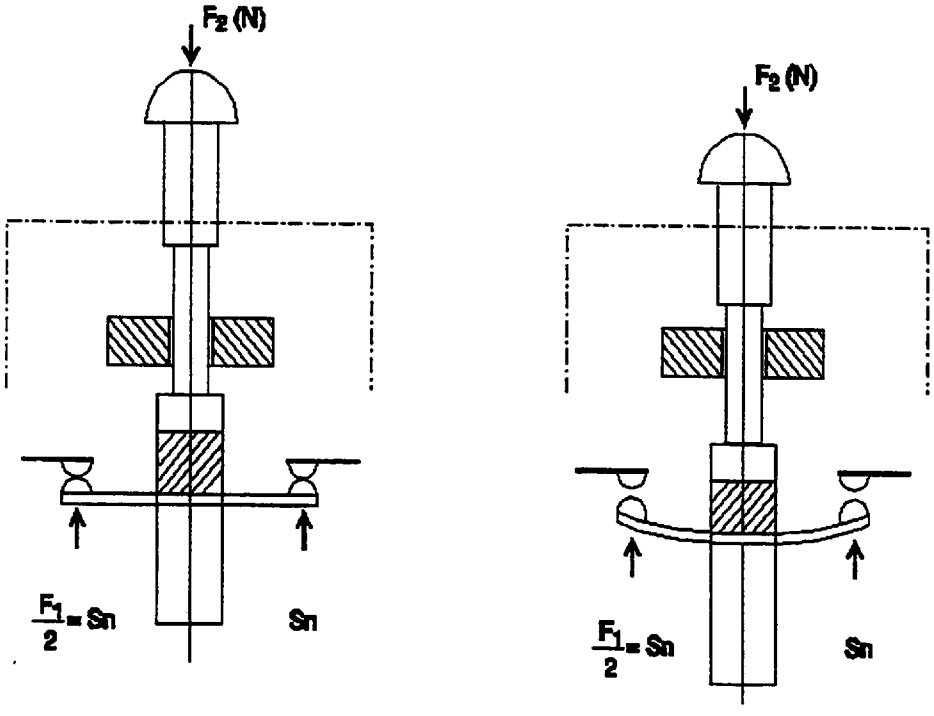


Figure 6-8-1
Verification Of Robustness

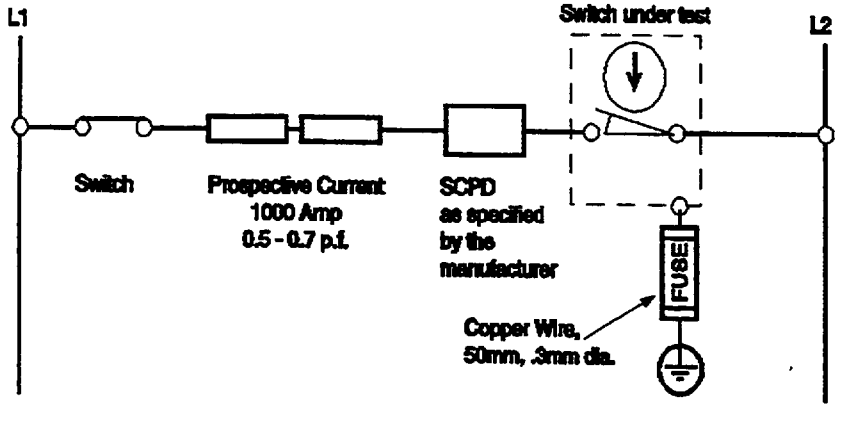


Figure 6-8-2
Short-Circuit Test Circuit

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9 APPLICATION

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ANNEX A
(Informative)
CLASSIFICATION OF PROXIMITY SWITCHES

Proximity switches may be classified according to various general characteristics as shown in Table A-1.

a. The sensing means is designated by a capital letter in the first position.
b. The mechanical installation is designated by one digit in the second position.
c. The construction form is designated by one capital letter in the third position.
d. The size is designated by two digits in the fourth position. These two numbers designate the size, e.g. the diameter of cylindrical types or a length of one side for rectangular types.
e. The switching element function is designated by a capital letter placed in the fifth position.
f. The type of output is designated by a capital letter and placed in the sixth position.
g. The method of connection is designated by a one-digit number placed in the seventh position.

Table A-1
Classification of proximity switches

1st position 1 digit	2nd position 1 digit	3rd position 1 digit	4th position/ 2 digits	5th position 1 digit	6th position 1 digit	7th position 1 digit
Sensing Means	**Mechanical Installation**	**Construction Form**	**Size (2 numbers)**	**Switching element function (Output)**	**Type of Output**	**Method of Connection**
I = Inductive C = Capacitive U = Ultrasonic D = Diffuse reflective photoelectric R = retroreflective photoelectric T = through beam photoelectric M_I = Magnetic, Internal M_E = Magnetic, External	1 = embeddable 2 = nonembeddable 3 = either	A = Cylindrical threaded barrel B = Cylindrical smooth barrel C = Square cross section D = Rectangular cross section	diameter or side length, mm	A = NO (make) B = NC (break) C = changeover (make/break) P = programmable by user S = other	P = PNP output 3 or 4 wire DC N = NPN output 3 or 4 wire DC D = 2 wire DC F = 2 wire AC U = 2 wire AC or DC S = other	1 = integral leads 2 = plug in 3 = screw 9 = other

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ANNEX B
(Informative)
TYPICAL PROXIMITY SWITCH SPECIFICATIONS

Proximity switches may be classified according to their dimensions and operating characteristics. The following specifications represent common dimensions and operating characteristics.

Type designations in the following specifications are described in Annex A *Classification Of Proximity Switches*.

B.1 Type I_A, Inductive cylindrical proximity switches with threaded barrel

B.1.1 Dimensions of Type I_A

The dimensions and thread sizes of typical cylindrical proximity switches with threaded barrel as shown in Figure B-1-1 are listed in Table B-1-1. Within the dimensional limits of d_1 and l_2 all rigid parts of the connecting leads shall be included. The diameter of unthreaded portion d_2 shall not exceed the minor diameter of the thread. For Type I_1, embeddable, the thread can be omitted and the diameter reduced to d_2 on a length not exceeding $l_3 = 1$ mm. For Type I_2 the thread can be omitted and the diameter reduced to d_2 on a length not exceeding $l_3 = 2\ s_n$.

Table B-1-1
Type I_A dimensions
Inductive cylindrical proximity switches with threaded barrel

Sensing means: Inductive (I)		Dimensions (mm)					
1 embeddable	2 non-embeddable	Body			Nuts		
Type		d_1 thread size	l_1 minimum	l_2 maximum	AF	m +0.15	d_3 max.
I1A08	I2A08	M8 x 1	40	60	13	4	15
I1A12	I2A12	M12 x 1	40	80	17	4	20
I1A18	I2A18	M18 x 1	50	100	24	4	28
I1A30	I2A30	M30 x 1.5	50	100	36	5	42

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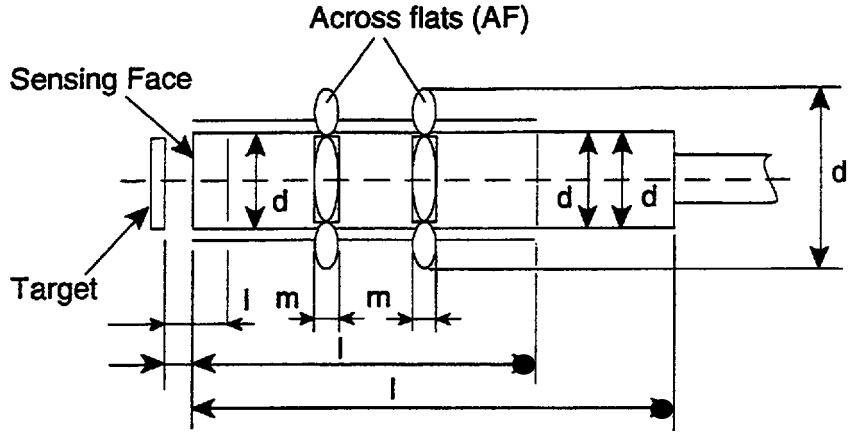


Figure B-1-1
Dimensions of Type I_A

B.1.2 Rated operating distances for Type I_A

The rated operating distance, for embeddable and nonembeddable proximity switches, shall be according to Table B-1-2. The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature.

B.1.3 Installation (mounting) of Type I_A

Embeddable proximity switches, when installed in damping material shall be according to Figure B-1-2(a).

Nonembeddable proximity switches, when installed in damping material shall be according to Figure B-1-2(b).

Table B-1-2
Type I_A Rated operating distances (mm)
Inductive cylindrical proximity switches with threaded barrel

Type I1_ - Embeddable		Type I2_ - Nonembeddable	
Form and Size	Rated Operating Distance (mm)	Form and Size	Rated operating Distance (mm)
A08	1	A08	2
A12	2	A12	4
A18	5	A18	8
A30	10	A30	15

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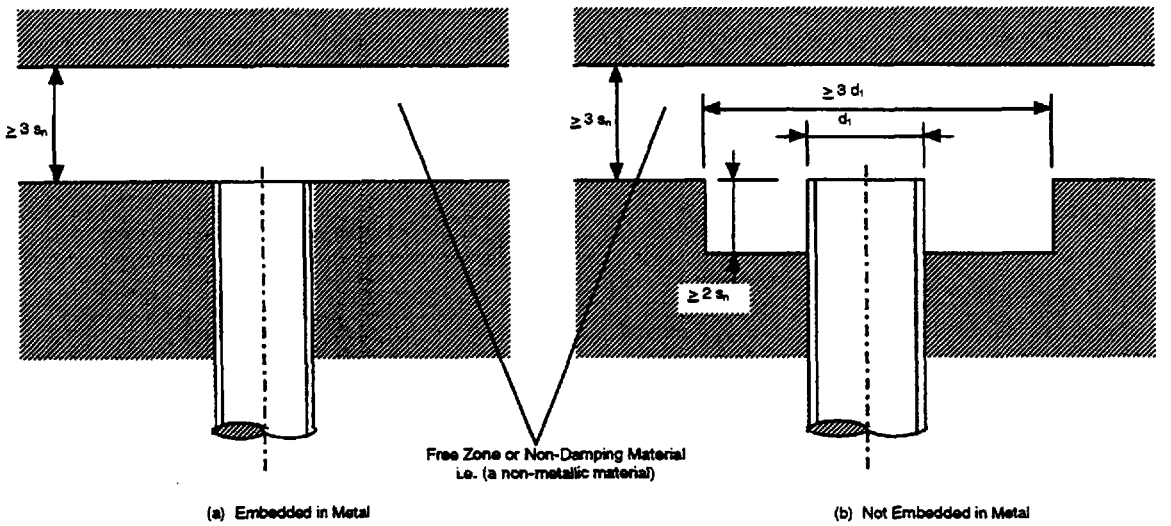


Figure B-1-2
Installation (mounting) of Type I_A

3.1.4 Standard frequency of operation, *f*, of Type I_A

The standard frequency of operation shall be according to Table B-1-3.

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Table B-1-3
Type I_A Standard frequency of operation
Inductive cylindrical proximity switches with threaded barrel

Form and Size	Installation	Switching element function: A or B		
		Type of Output		
		P or N Hz	D Hz	F Hz
A08	1	500	300	
	2	300	200	
				5
A12	1	400	200	
	2	200	100	
A18	1	200	100	
	2	100	50	
A30	1	70	50	
	2	50	30	

B.2 Type I_B, Inductive cylindrical proximity switches with smooth barrel

B.2.1 Dimensions of Type I_B

The dimensions shown in Figure B-2-1 shall be according to Table B-2-1. Within the dimensional limits of d_1 and l_2 all rigid parts of the connecting leads shall be included.

No part of the proximity switch within the length l_2 shall exceed the diameter d_1.

Table B-2-1
Type I_B dimensions
Inductive cylindrical proximity switches
with smooth barrel

Sensing means: Inductive (I)	Dimensions mm			
_1_ Embeddable Type	d_1	l_1 minimum	l_2 maximum	l_3 maximum
I1B04	4	25	50	0.5
I1B06	6.5	40	60	1

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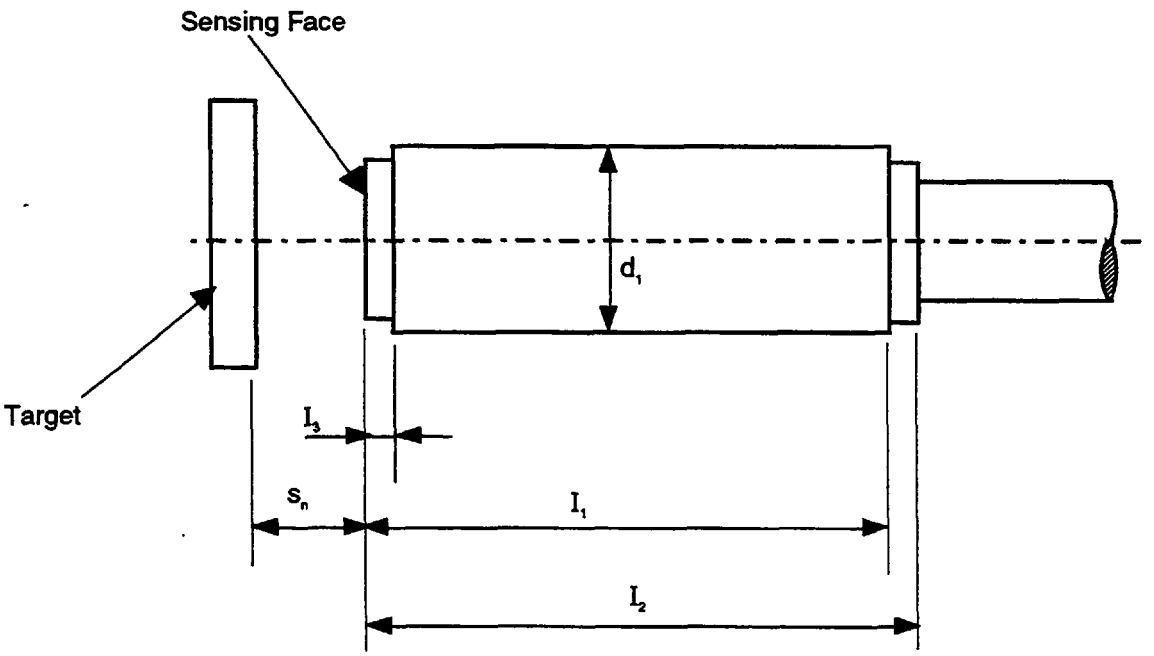


Figure B-2-1
Dimensions IB

B.2.2 Rated operating distances for Type I_B

The rated operating distance shall be according to Table B-2-2. The rated operating distance is a conventional quantity. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature.

Table B-2-2
Type I_B rated operating distance (mm)
Inductive cylindrical proximity switches with smooth barrel

Type I1_ - Embeddable	
Type	**Rated operating distance**
B04	0.8
B06	1

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B.2.3 Installation (mounting) of Type I_B

The proximity switch when installed in damping material shall be according to Figure B-2-2.

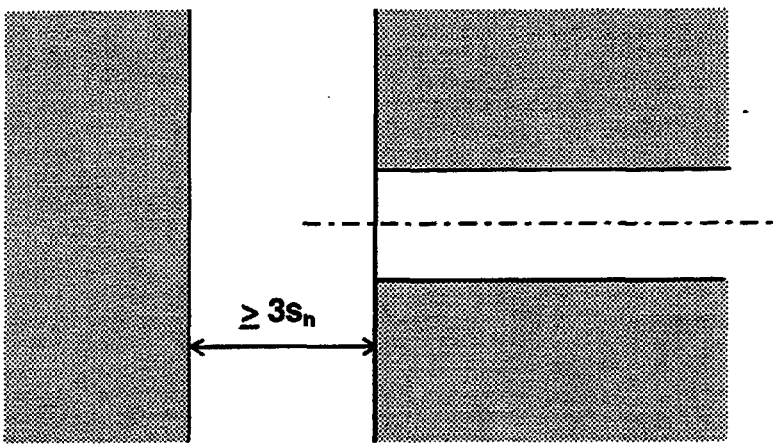


Figure B-2-2
Installation of Type I_B in damping material

B.2.4 Standard frequency of operation *f* of Type I_B

The standard frequency of operation shall be according to Table B-2-3.

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.3 Type I_C, Inductive rectangular proximity switches with square cross section

▭.3.1 Dimensions of Type I_C

B.3.1.1 Type I1C26 inductive, embeddable, 26 mm x 26 mm

Overall mounting and dimensions shall be according to Figure B-3-1. The rigid part of the cable assembly is included in the overall dimensions. The cable entry shall allow the passage and ensure the anchorage as well as the tightness of a cable with an external diameter of 7 mm to 10 mm.

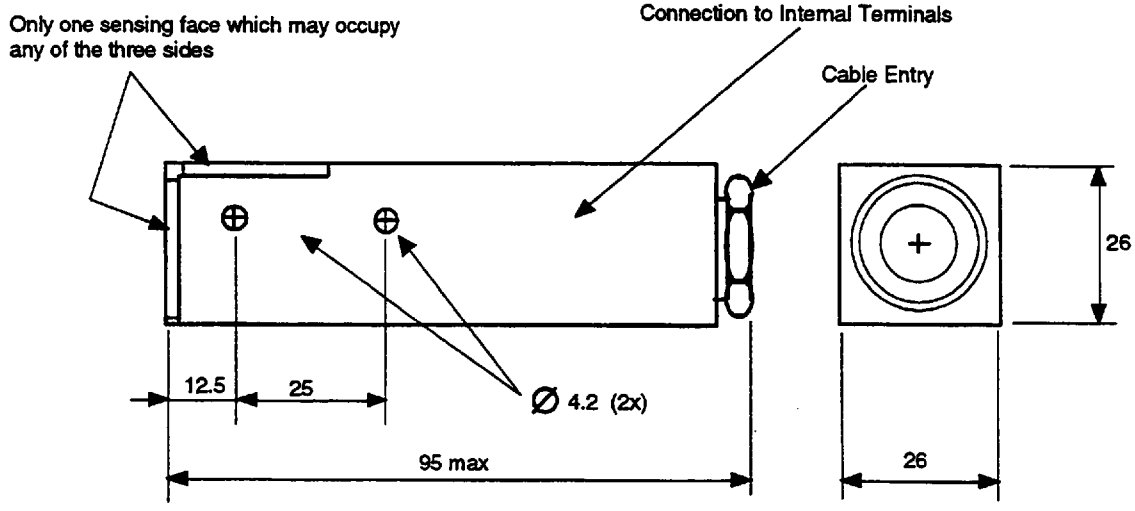


Figure B-3-1
Dimensions of Type I1C26

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B.3.1.2 Type I2C35 inductive, nonembeddable, 35 mm x 35 mm

Overall mounting and dimensions shall be according to Figure B-3-2. The rigid part of the cable assembly is included in the overall dimensions.

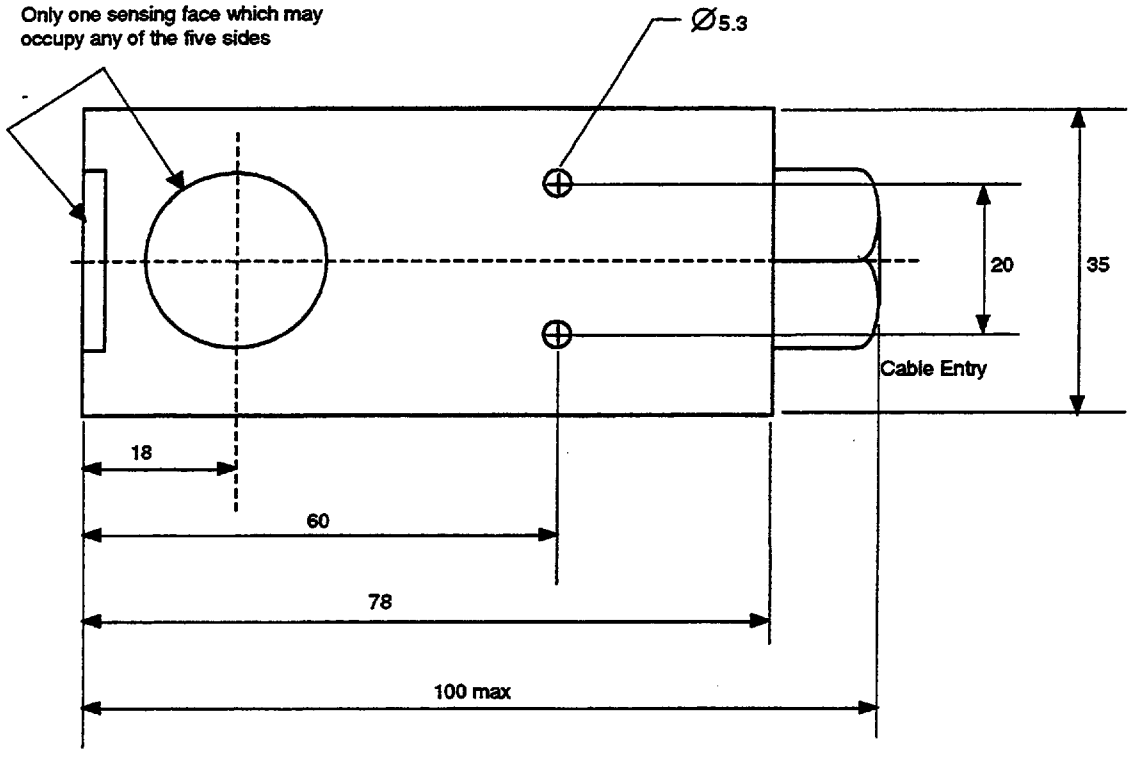


Figure B-3-2
I2C35 Dimensions

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3.1.3 Type I2C30 inductive, nonembeddable and Type I1C30 inductive embeddable 30 x 30 mm.

Overall mounting and dimensions shall be according to Figure B-3-3. The rigid part of the cable assembly is not included in the overall dimensions.

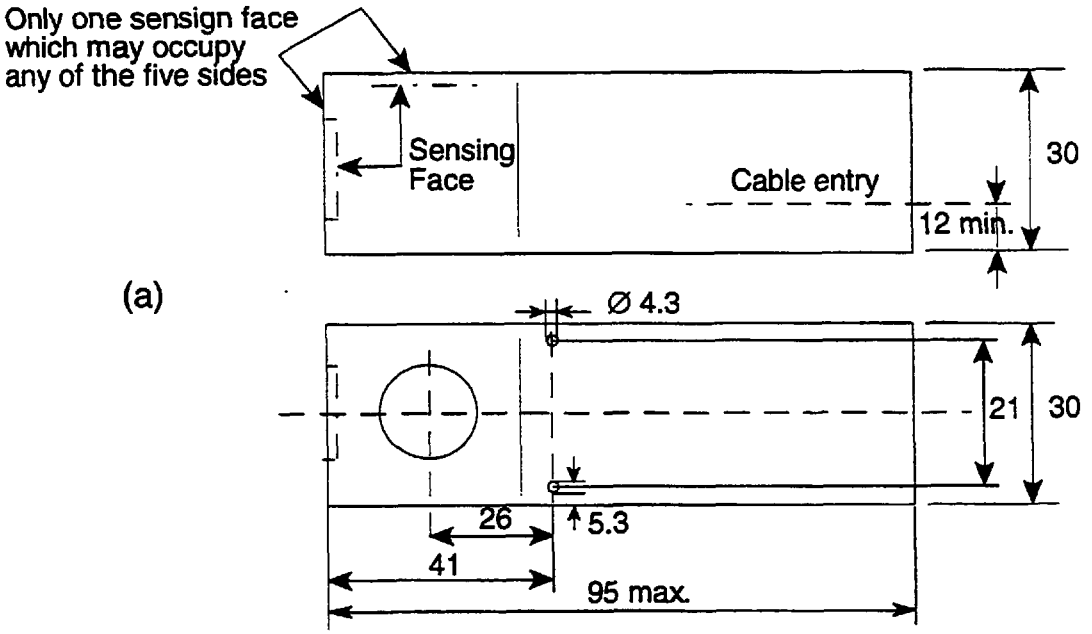


Figure B-3-3
Dimensions of Type I2C30

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B.3.1.4 Type I2C40 inductive, nonembeddable and Type I1C40 inductive embeddable 40 x 40 mm

Overall mounting and dimensions shall be according to Figure B-3-4. The rigid part of the cable assembly is not included in the overall dimensions.

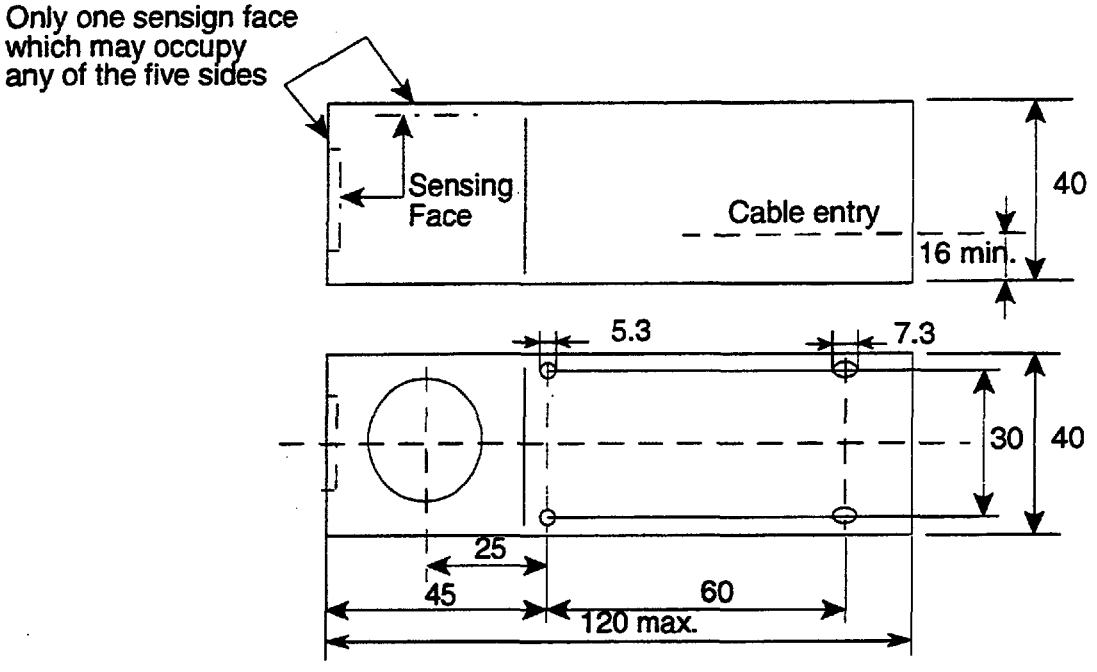


Figure B-3-4
Dimensions of Type I2C40

B.3.2 Rated operating distances for Type I_C

The rated operating distance shall be according to Table B-3-1. The rated operating distance is a conventional quantity. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature.

Table B-3-1
Type I_C, Rated operating distance (mm)
Inductive rectangular proximity switches with square cross section

Type	Rated operating distance
I1C26 embeddable	10
I1C35 nonembeddable	15
I1C40 embeddable	15
I2C40 nonembeddable	20
I1C30 embeddable	10
I2C30 nonembeddable	15

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.3.3 Installation (mounting) of Type I_C

ɒ.3.3.1 Type I1C proximity switch installed in damping material

Type I1C proximity switch installed in damping material is shown in Figure B-3-5. Figure B-3-5(a) shows the proximity switch with front sensing face, and Figure B-3-5(a) shows the proximity switch with side sensing face installed.

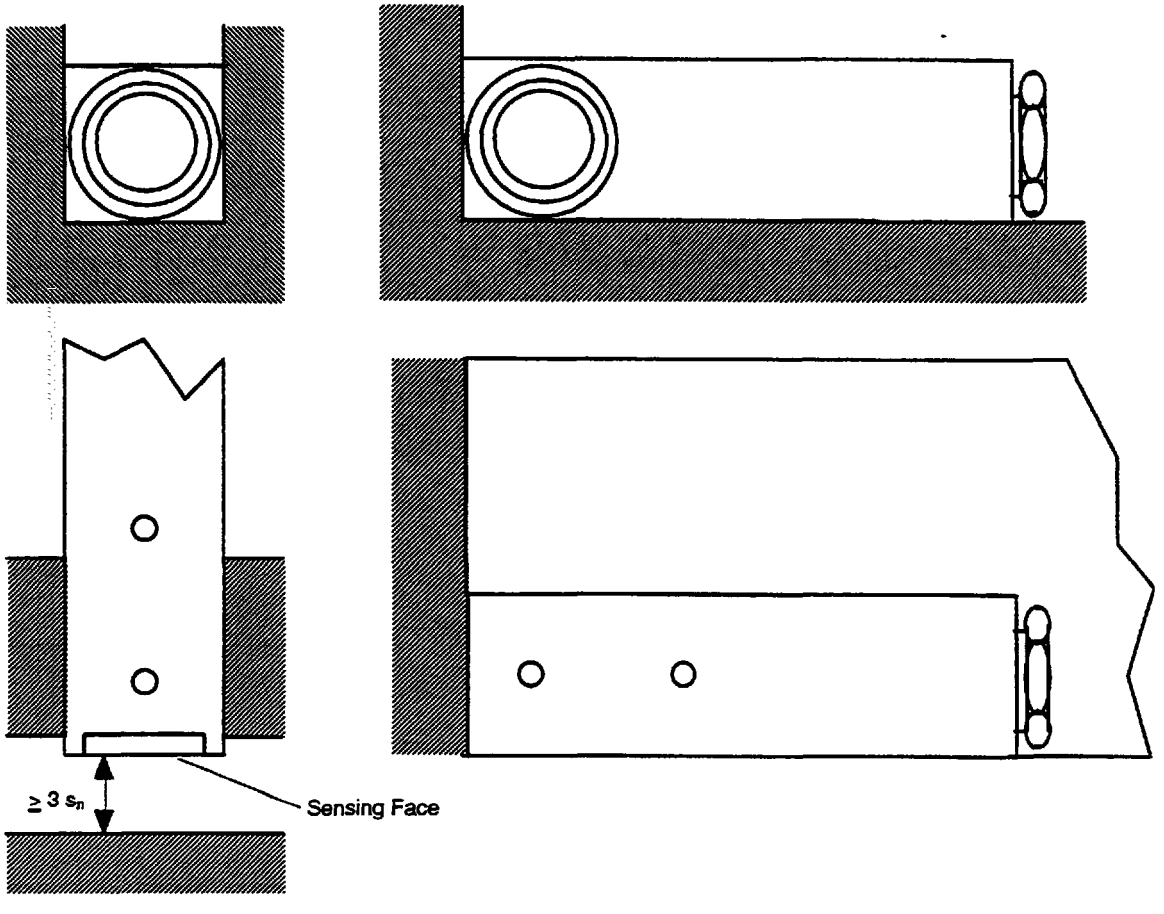
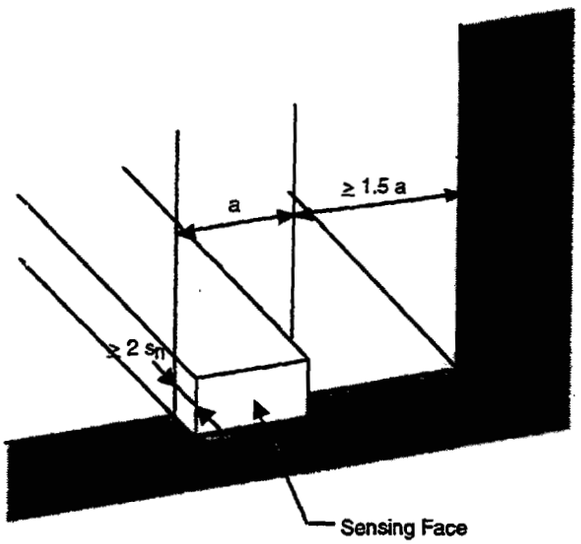


Figure B-3-5
Installation of Type I1C in damping material

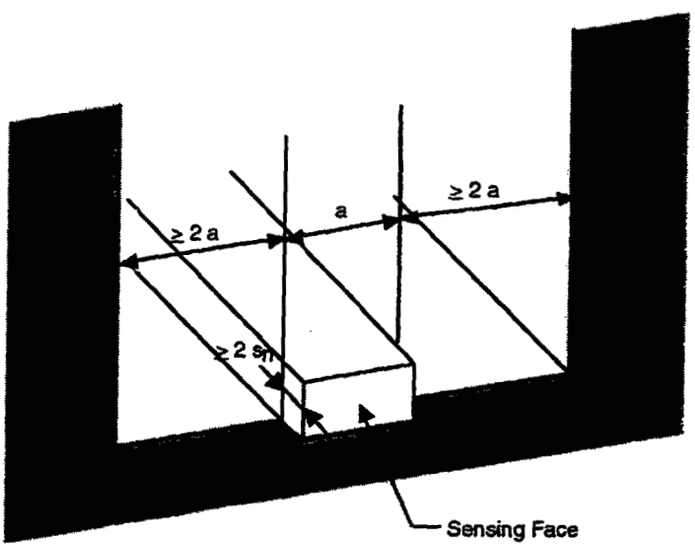
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B.3.3.2 Type I2C proximity switch installed in damping material

Type I2C proximity switch installed in damping material is shown in Figure B-3-6.



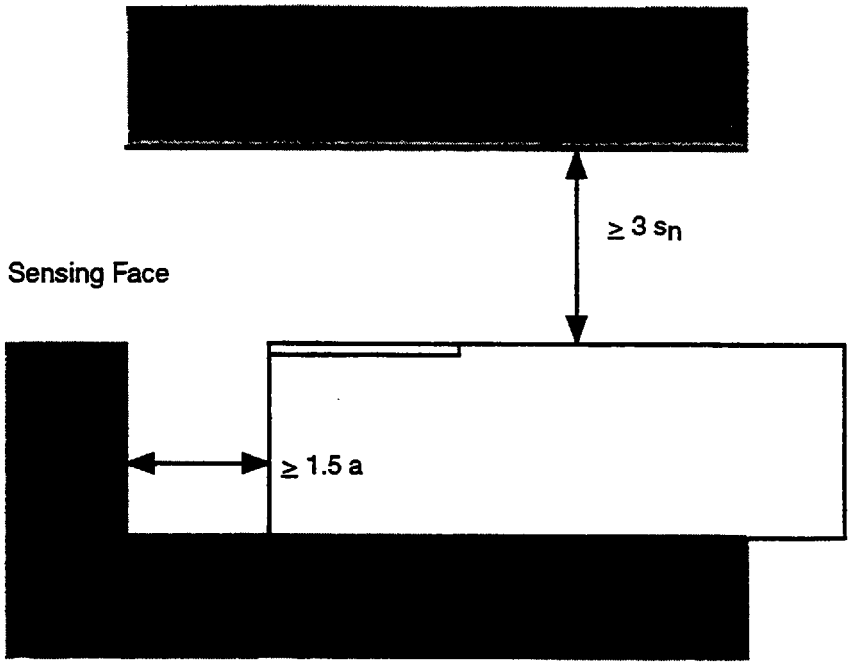
(a) Angle Mounting



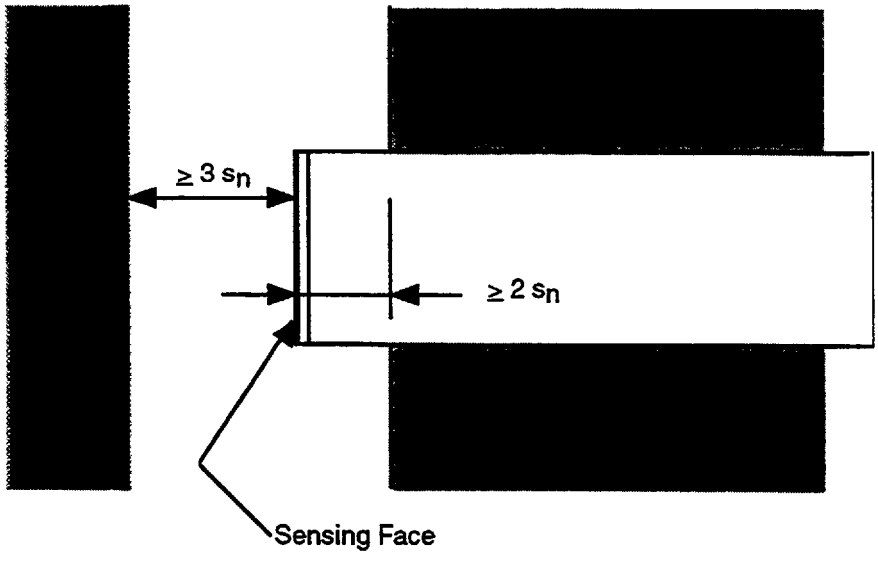
(b) Channel Mounting

Figure B-3-6
Installation of Type I2C35 in damping material

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(d) Not Embedded in Damping Material



(c) Embedded in Damping Material

Figure B-3-6 (continued)
Installation of Type I2C35 in damping material

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B.3.4 Standard frequency of operation *f* of Type I_C

The standard frequency of operation shall be according to Table B-3-2.

Table B-3-2
Type I_C Standard frequency of operation
Inductive rectangular proximity switches with square cross-section

Form and Size	Installation	Switching element function: A or B Type of Output P or N hertz	D hertz	F hertz
_C26	1	40	40	
_C35	2	100	50	5
_C30	1	70	50	
_C40	1	50	50	

B.4 Type I_D, Inductive rectangular proximity switches with rectangular cross-section

B.4.1 Dimensions of Type I_D

Type I2D nonembeddable proximity switches shall have overall and mounting dimensions shall be according to Figure B-4-1 and Table B-4-1. Parts of the cable assembly are not included in the overall dimensions.

Table B-4-1
Type I_D Dimensions
Inductive rectangular proximity switches with rectangular cross-section

Type	l_1 max	$l_2 = b_2$	b_1 max
I2D60	120	45	50
I2D80	135	65	80

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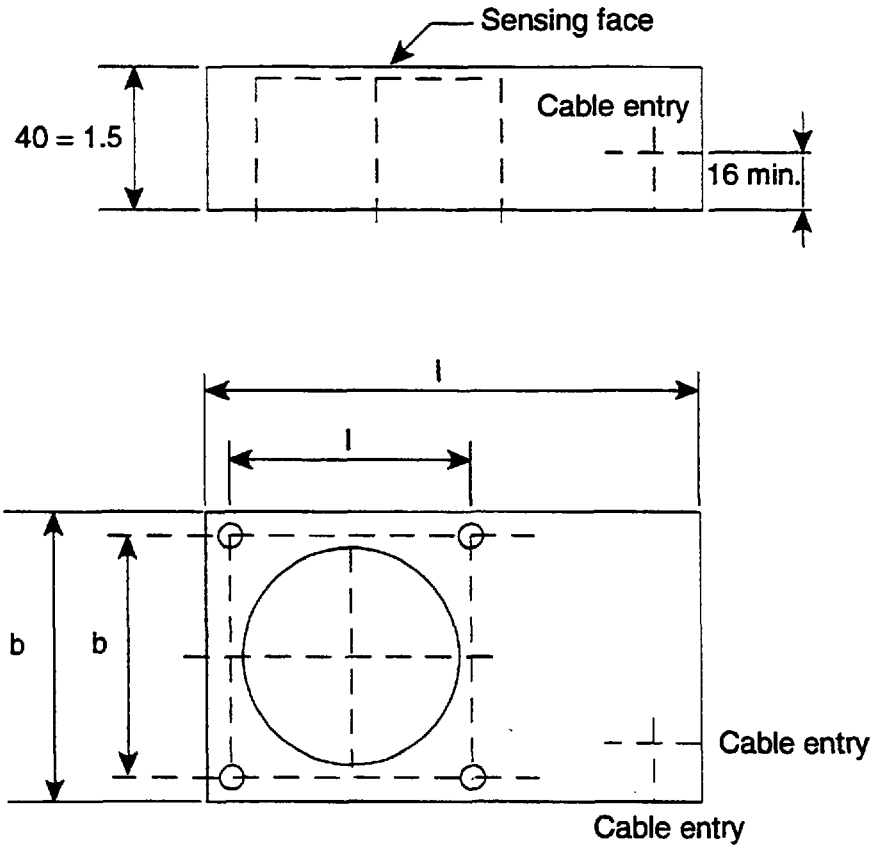


Figure B-4-1
Dimensions of Type I2D

B.4.2 Rated operating distances for Type I_D

The rated operating distance for nonembeddable proximity switches shall be according to Table B-4-2. The rated operating distance is a conventional quantity. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature.

Table B-4-2
Type I_D, Rated operating distances (mm)
Inductive rectangular proximity switches with rectangular cross-section

Type	Rated operating distance
I2D60 nonembeddable	25
I2D80 nonembeddable	40

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B.4.3 Installation (mounting) of Type I_D

The installation of I2D60 and I2D80 proximity switches in damping material is shown in Figure B-4-2.

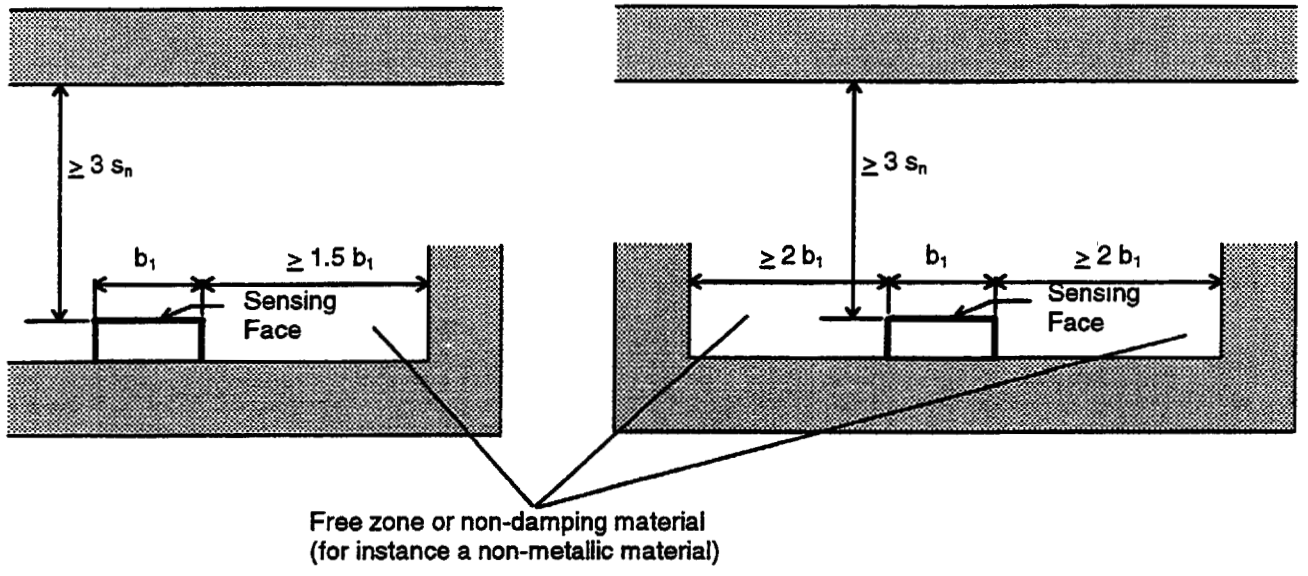


Figure B-4-2
Installation of Type I2D in damping material

B.4.4 Standard frequency of operation *f* of Type I_D

The standard frequency of operation shall be according to Table B-4-3.

Table B-4-3
Type I_D Standard frequency of operation
Inductive rectangular proximity switches with rectangular cross section

Form and Size	Installation	Switching element function: A or B Type of Output P or N	D	F
D60	2	25	15	5
D80	2	10	10	5

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.5 Type C_A, Capacitive cylindrical proximity switches with threaded barrel

.5.1 Dimensions of Type C_A

The dimensions of thread sizes shown in Figure B-5-1 shall be according to Table B-5-1. Within the dimensional limits of d_1 and l_2, all rigid parts of the connecting leads shall be included. The diameter of unthreaded portion d_2 shall not exceed the minor diameter of the thread. The thread can be omitted and the diameter reduced to d_2 on a length not exceeding $l_3 \leq 2 \times s_n$

Table B-5-1
Type C_A Dimensions (mm)
Capacitive cylindrical proximity switches with threaded barrel

Sensing Means: capacitive (C)	Dimensions					
	Body			Nuts		
Type	d_1 thread size	l_1 min	l_2 max.	AF	m +0.15	d_3 max
C_A18	M18x1	50	100	24	4	28
C_A30	M30x1.5	50	100	36	5	42

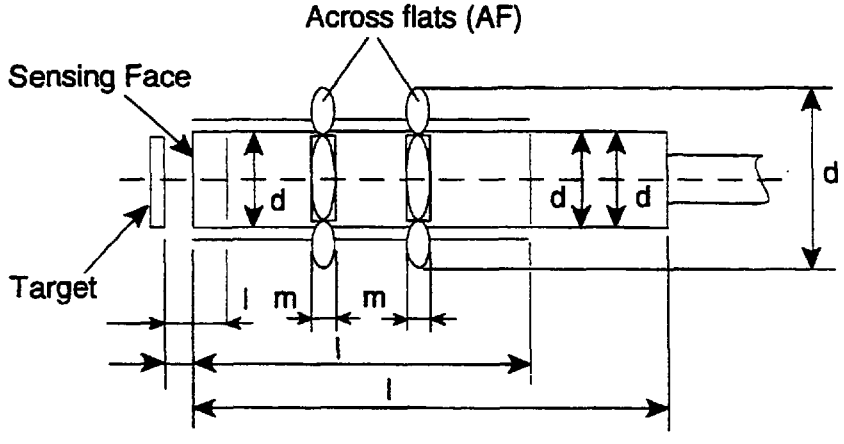


Figure B-5-1
Dimensions of Type C_A

B.5.2 Rated operating distance s_n for Type C_A

The rated operating distance is adjusted by the manufacturer under mounting conditions stated in B.5.3.

The rated operating distance shall be set according to Table B-5-2. The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as voltage, temperature, humidity and mounting conditions.

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Table B-5-2
Type C_A, Rated operating distance (mm)
Capacitive cylindrical proximity switches with threaded barrel

Type	Rated operating distance
C_A18	5
C_A30	10

B.5.3 Installation (mounting) of Type C_A

The capacitive proximity switch shall be mounted according to Figure B-5-2.

B.5.4 Standard frequency of operation *f* of Type C_A

The minimum requirements for capacitive proximity switch shall be 10 operating cycles per second for Type C_A18 and Type C_A30.

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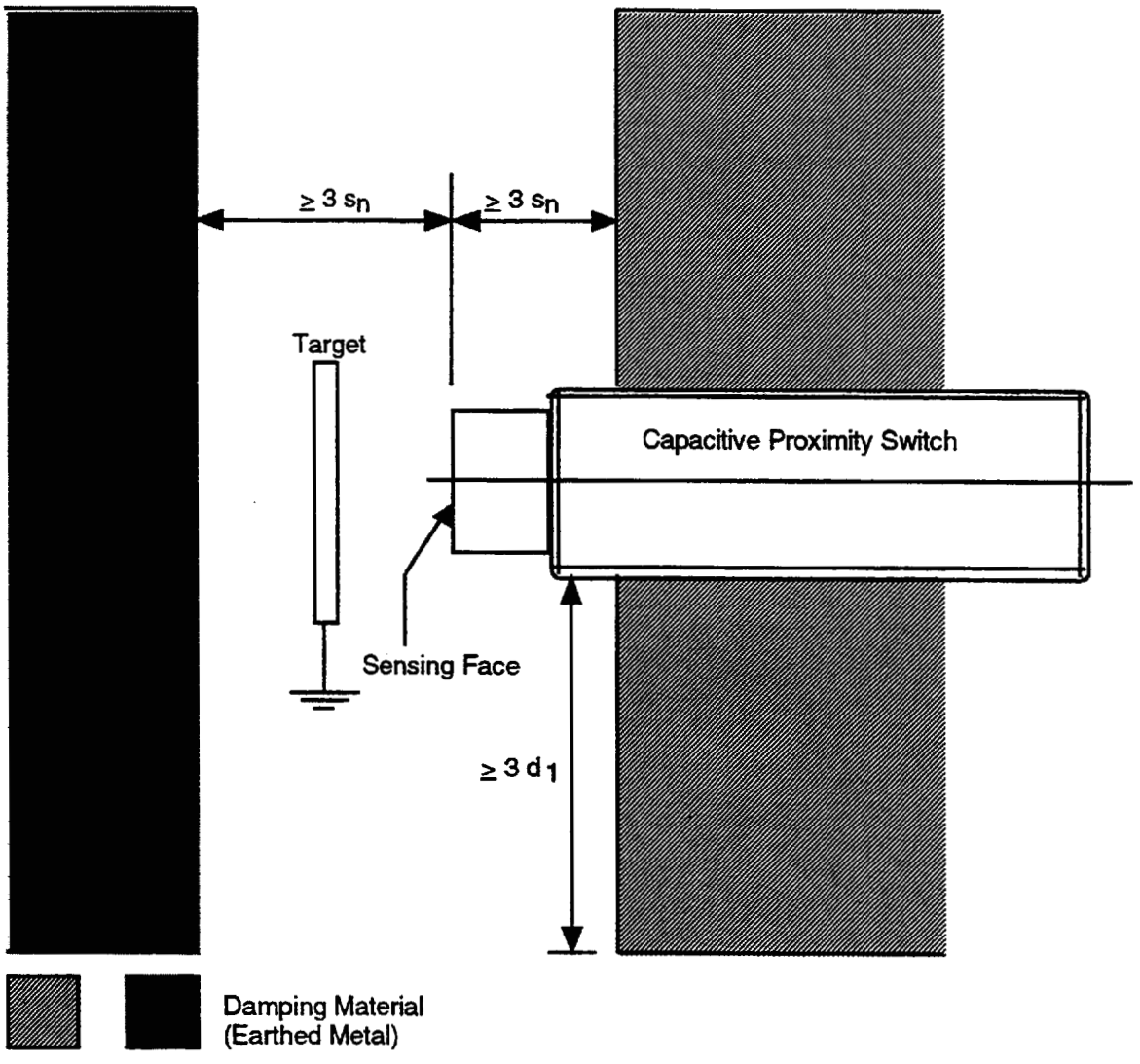


Figure B-5-2
Installation of Type C_A

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B.6 Type C_C, Capacitive rectangular proximity switches with square cross section

B.6.1 Dimensions of Type C_C

Overall and mounting dimensions of Type C_C30 shall be according to Figure B-6-1(a), and for Type C_C40 shall be according to Figure B-6-1-(b). Apart from these dimensions, the design shall no be restricted. The mounting dimensions are included within the dimensions of the housing, but the cable entry dimensions are not.

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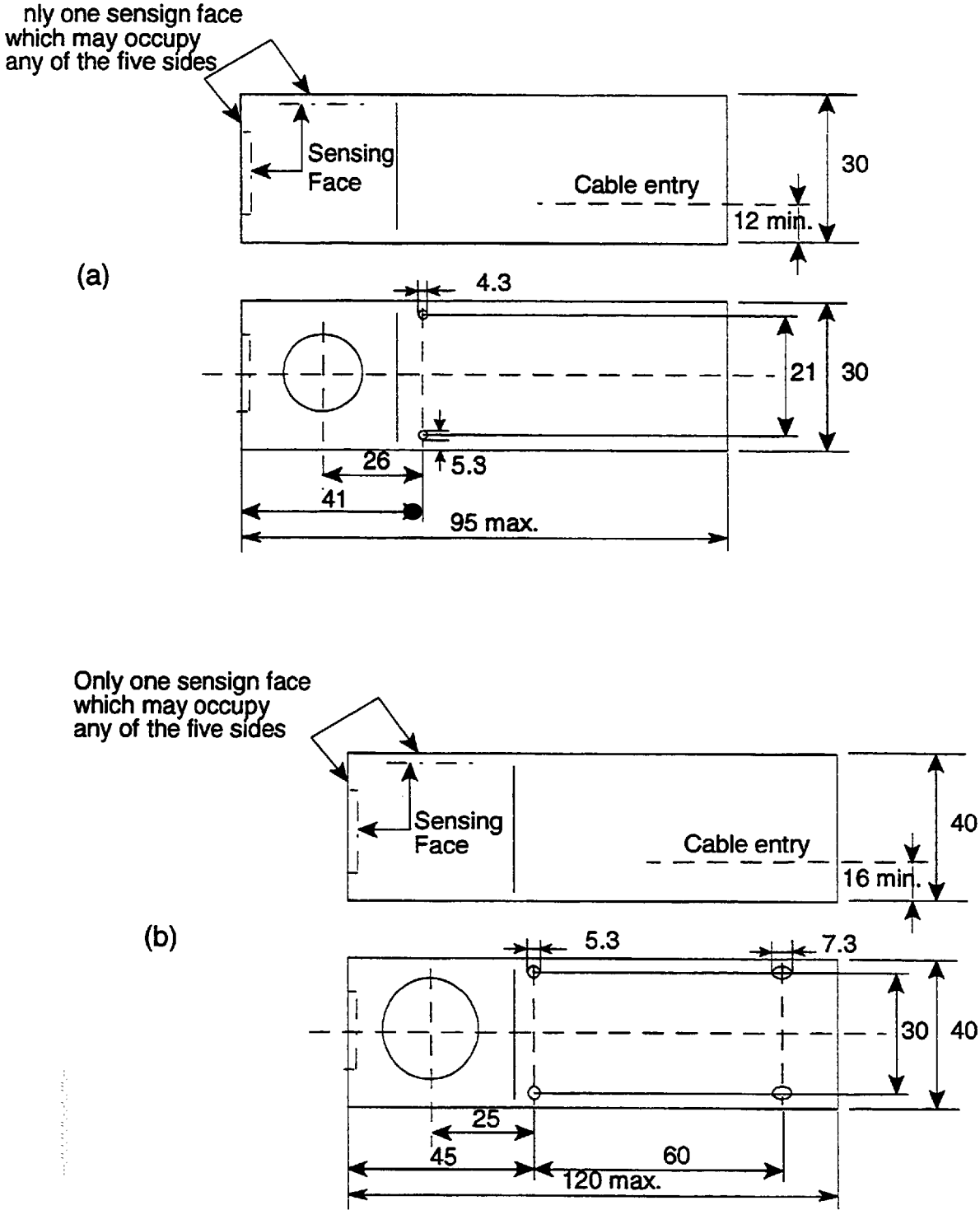


Figure B-6-1
Dimensions of Type C_C,
Capacitive rectangular with square cross-section

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B.6.2 Rated operating distances s_n for Type C_C

The rated operating distance is adjusted by the manufacturer under mounting conditions stated in B.6.3.

The rated operating distance shall be set according to Table B-6-1. The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as voltage, temperature, humidity and mounting conditions.

Table B-6-1
Type C_C Rated operating distance (mm)
Capacitive rectangular proximity switches with square cross-section

Type	Rated operating distance
C_C18	10
C_C30	15

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.6.3 Installation (mounting) of Type C_C

The capacitive proximity switch shall be mounted according to Figure B-6-2.

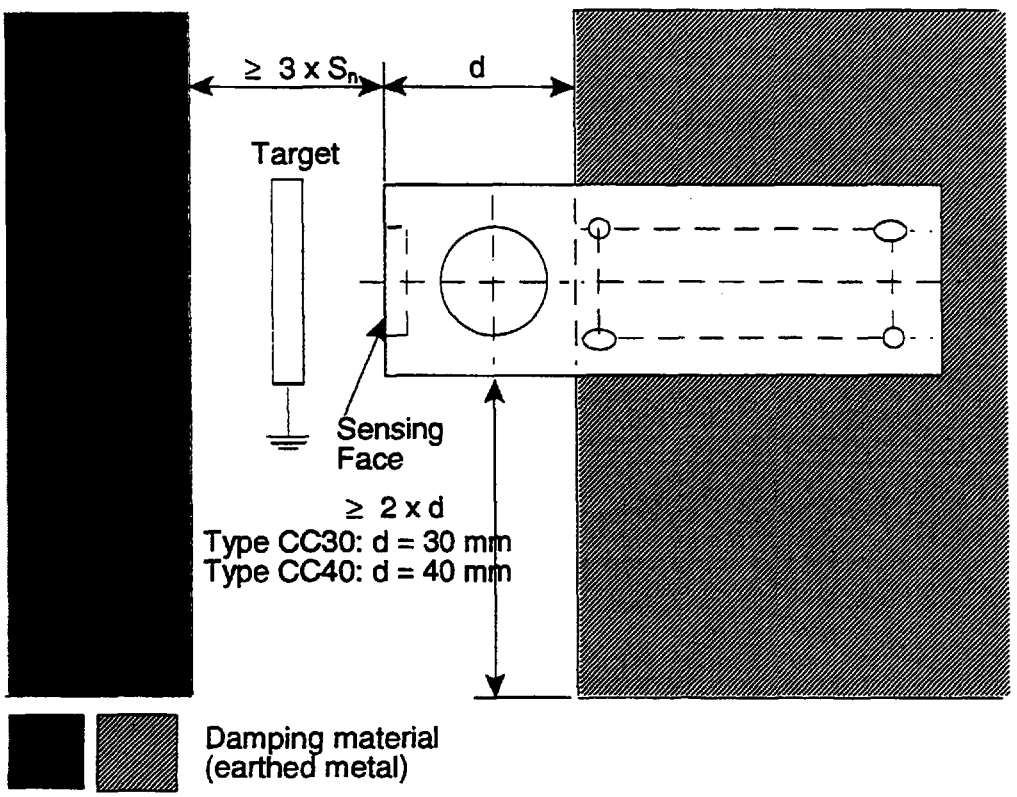


Figure B-6-2
Installation of Type C_C

B.6.4 Standard frequency of operation *f* of Type C_C

The minimum requirements for capacitive proximity switch shall be 10 operating cycles per second for Type C_C30 and Type C_C40.

B.7 Type C_D, Capacitive rectangular proximity switches with rectangular cross-section

B.7.1 Dimensions of Type C_D

Type C_D80 proximity switches shall have overall and mounting dimensions according to Figure B-7-1. Parts of the cable assembly are no included in the overall dimensions.

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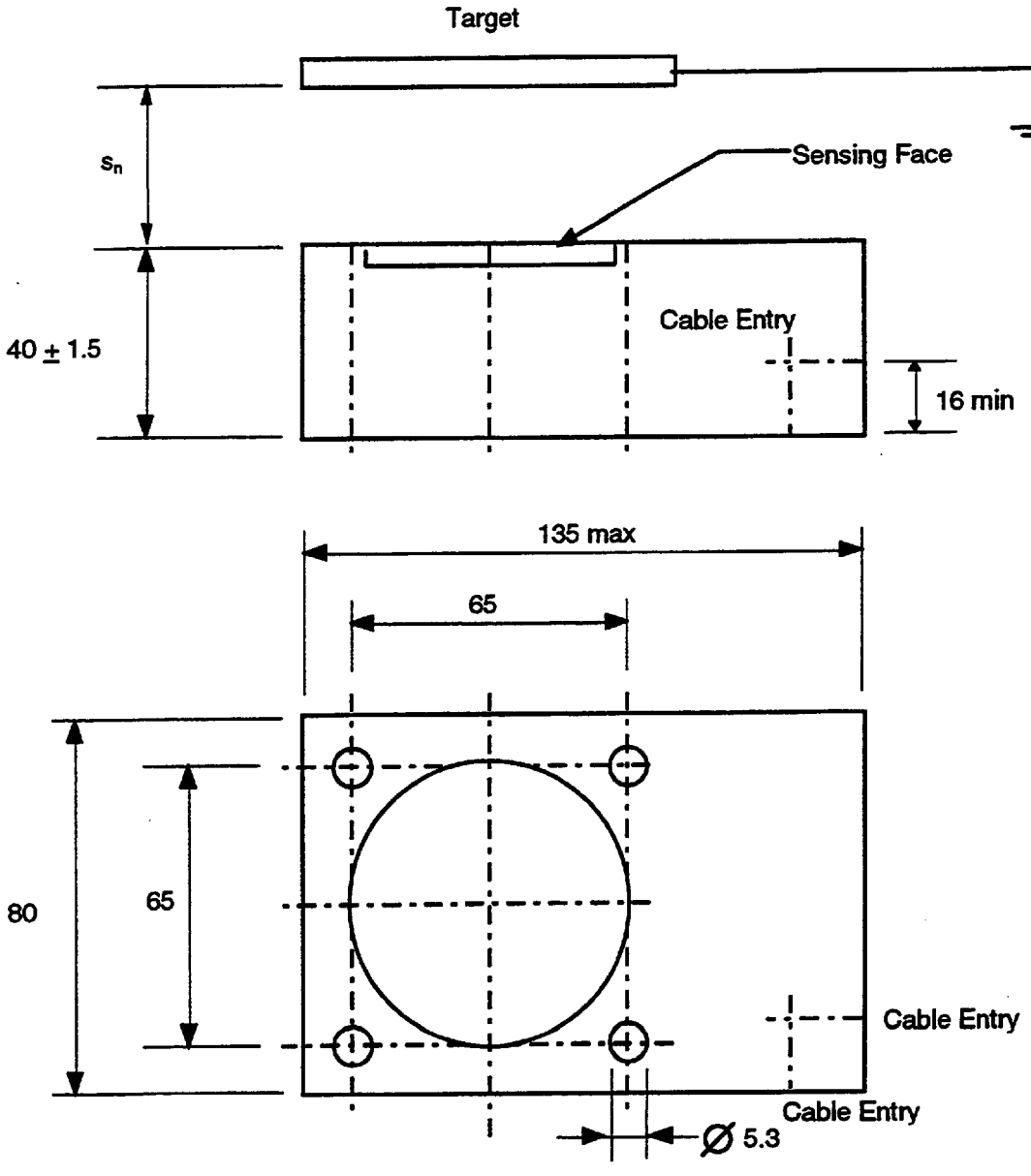


Figure B-7-1
Dimensions of Type C_D

B.7.2 Rated operating distance s_n for Type C_D

The rated operating distance is adjusted by the manufacturer under mounting conditions stated in B.7.3.

The rated operating distance shall be: s_n = 40 mm.

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The rated operating distance is a conventional quantity, it does not take into account either manufacturing tolerances or variations due to external conditions such as installation (mounting), voltage, humidity and temperature.

B.7.3 Installation (mounting) of Type C_D

The proximity switch shall be mounted on damping material. The dimensions of the damping material shall be at least three times the outside dimensions of the capacitive proximity switch.

Damping material in opposite of the sensing face shall not be closer than 3 x s_n. See Figure B-7-2.

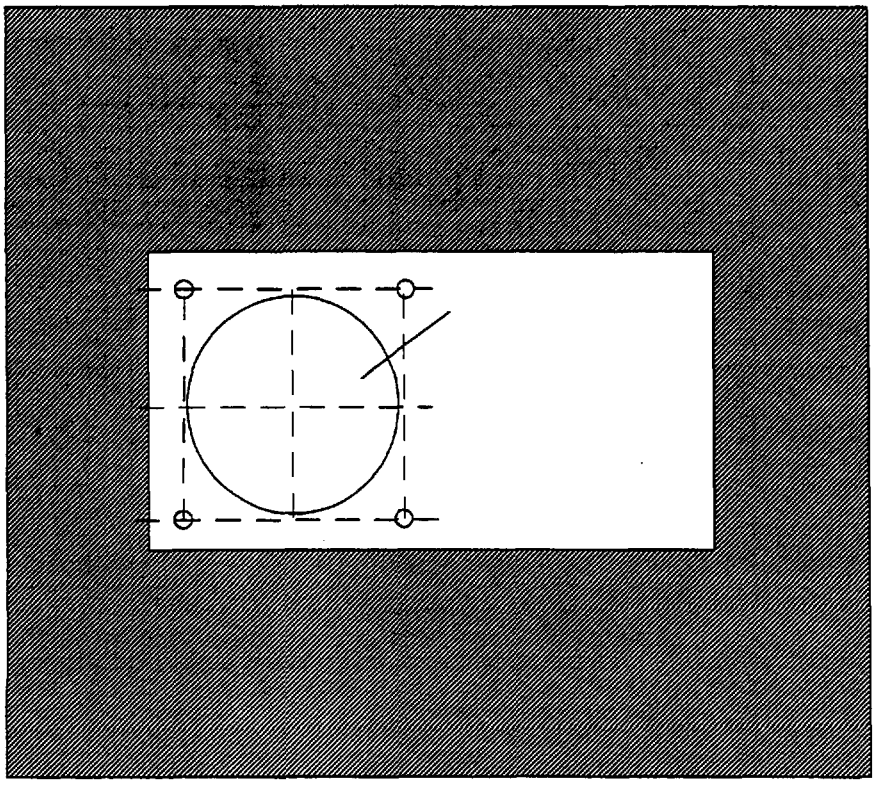


Figure B-7-2
Installation of Type C_D

B.7.4 Standard frequency of operation *f* of Type C_D

The minimum requirements for standard frequency of operation shall be 10 operating cycles per second.

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B.8 Type U_A, Threaded barrel ultrasonic cylindrical proximity switches

B.8.1 Dimensions of Type U_A

The dimensions and thread size shown in Figure B-8-1 shall be according to Table B-8-1. Within the dimensional limits of d_1 and l_2, all rigid parts of the connecting leads shall be included. The diameter d_2 may exceed the diameter of the thread according to extended sensing ranges. The diameter d_4 of the unthreaded part shall not exceed the minor diameter of the thread.

Table B-8-1
Type U_A, Dimensions
Threaded barrel ultrasonic cylindrical proximity switches

		Dimensions							
		Body					Nuts		
Type	Sensing range	d_1 thread size	d_2	l_1 min	l_2 max	l_3	AF	m +0.15	d_3 max
U3A18	A	M18x1	M18	30	100	0	24	4	28
U3A30	A	M30x1.5	M30	50	150	0	36	5	42
U3A30	B	M30x1.5	M30	50	150	0	36	5	42
U3A30	E	M30x1.5	70 max	50	150	35	36	5	42
U3A42	D	M42x1	M42	35	150	0	50	6	57
U3A42	E	M42x1	70 max	50	150	35	50	6	57

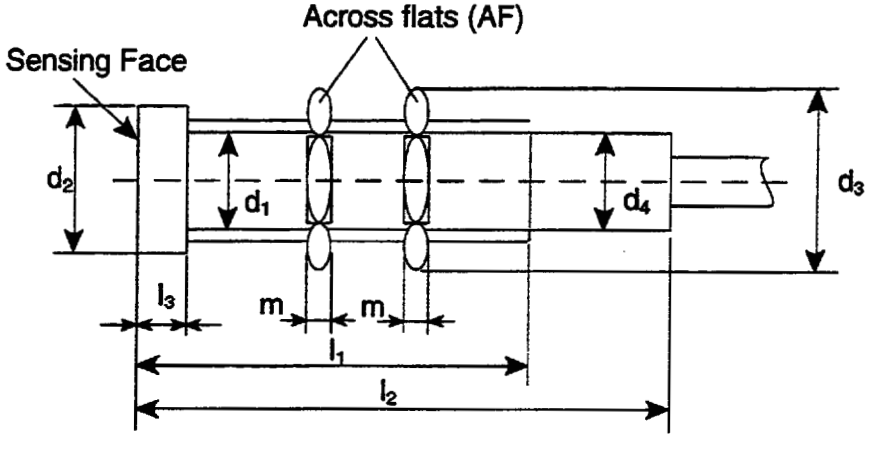


Figure B-8-1
Dimensions of Type U_A

B.8.2 Sensing range of Type U_A

The operating distances maximum and minimum for ultrasonic proximity switches shall be according to Table B-8-2. These distances are conventional quantities, they do not take into account variations due to external conditions such as temperature, altitude and humidity.

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Table B-8-2
Type U_A Requirements for sensing range (mm)
Threaded barrel ultrasonic cylindrical proximity switches

Sensing Range	minimum	maximum	Target Size (mm)
A	60	300	10 x 10
B	300	800	20 x 20
D	500	2000	100 x 100
E	800	6000	100 x 100

B.8.3 Installation (mounting) of Type U_A

According to manufacturers instructions.

B.8.4 Standard frequency of operation *f* of Type U_A

The standard frequency of operation shall be stated by the manufacturer either in operating cycles per second or in operating cycles per minute.

B.9 Type U_C, Ultrasonic rectangular proximity switches with square cross-section

B.9.1 Dimensions of Type U_C

Overall and mounting dimensions shall be according to Figure B-9-1. Apart form these dimensions, ıe design of the proximity switch is not restricted. Within the overall dimensions of the housing, the ..ıounting dimensions are included but the cable entry dimensions are not included.

Table B-9-1
Type U_C Sensing range (mm)
Ultrasonic rectangular proximity switches with square cross section

Sensing range	minimum	maximum	Target size (mm)
A	60	300	10 x 10
C	300	1000	20 x 20

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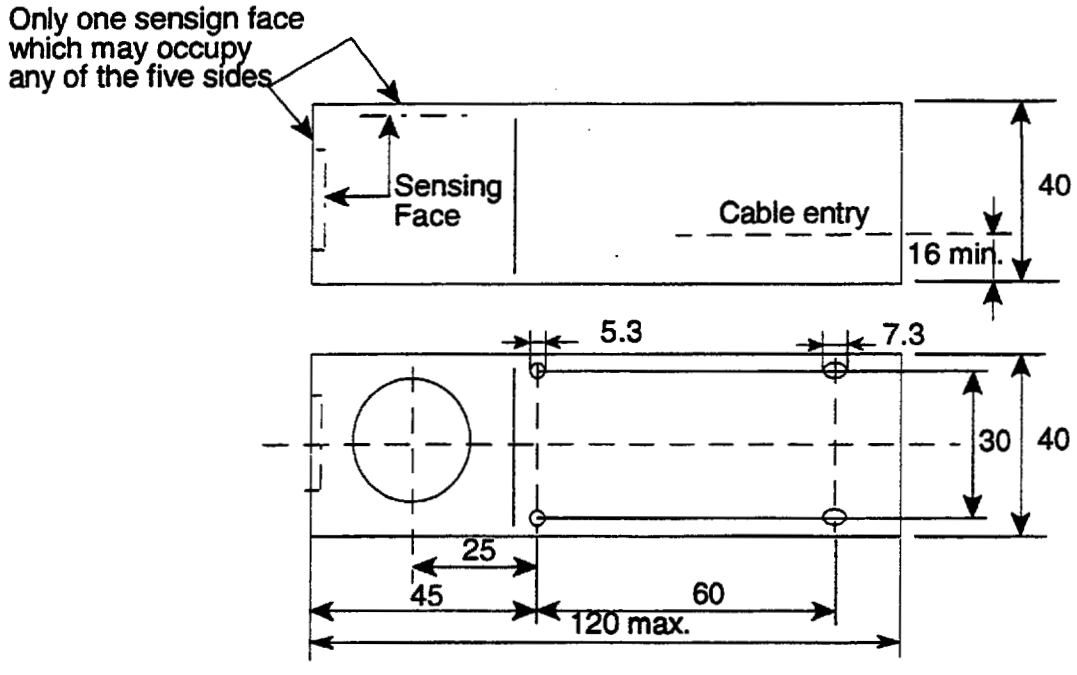


Figure B-9-1
Type U3C40 Dimensions

B.9.2 Sensing range for Type U_C

The maximum and minimum operating distances for ultrasonic proximity switches shall be according to Table B-9-1. These distances are conventional quantities, they do not take into account variations due to external conditions such as temperature, altitude and humidity.

B.9.3 Installation (mounting) of Type U_C

According to manufacturers instructions.

B.9.4 Standard frequency of operation *f* of Type U_C

The standard frequency of operation shall be stated by the manufacturer either in operating cycles per second or in operating cycles per minute.

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10 Type U_D, Ultrasonic rectangular proximity switches with rectangular cross-section

B.10.1 Dimensions of Type U_D

Type U3D80 ultrasonic proximity switches shall have overall and mounting dimensions according to Figure B-10-1. Parts of the cable assembly are not included in the overall dimensions.

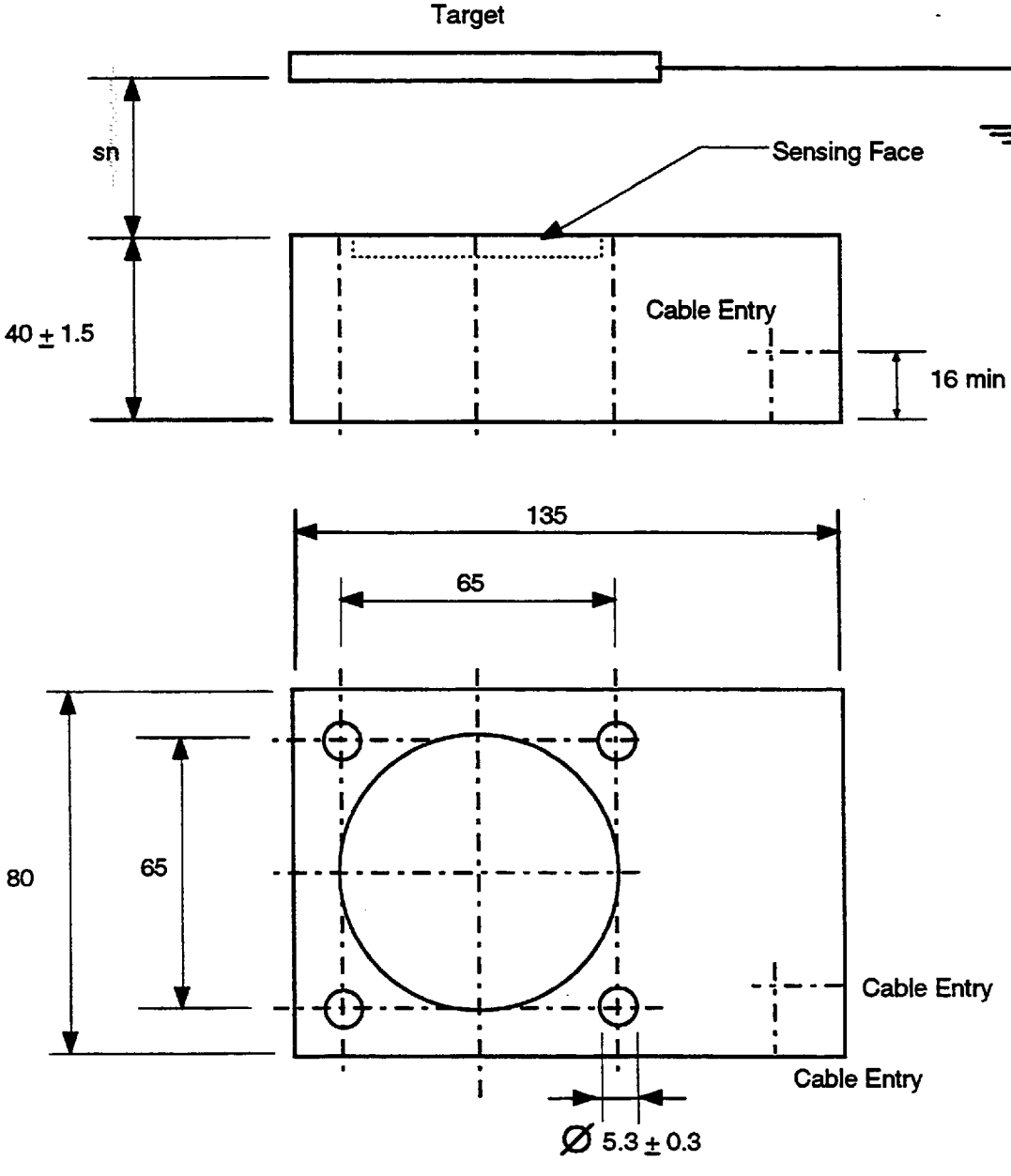


Figure B-10-1
Dimensions of Type U3D80

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B.10.2 Sensing range of Type U_D

The operating distances shall be according to Table B-10-1. These distances are conventional quantities, they do not take into account variations due to external conditions such as temperature, altitude and humidity.

Table B-10-1
Type U_D Sensing range (mm)
Ultrasonic rectangular proximity switches with rectangular cross section

Sensing range	minimum	maximum	Target size (mm)
A	60	300	10 x 10
C	300	1000	20 x 20
E	800	6000	100 x 100

B.10.3 Installation (mounting)

According to manufacturers instructions.

B.10.4 Standard frequency of operation *f* of Type U_D

The standard frequency of operation shall be stated by the manufacturer either in operating cycles per second or in operating cycles per minute.

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ANNEX C
(Normative)
PROGRAMMABLE LOGIC CONTROLLERS (PLC) COMPATIBILITY

C-1 General

Proximity switch/PLC compatibility specifications are shown in Table C-1

The proximity switch operating parameters that must meet Proximity Switch/PLC Compatibility specifications are:

I_m = Minimum operational current
I_r = OFF-State current
U_d = Voltage drop
$U_{b\,min}$ = Minimum operational voltage

The PLC operating parameters that must meet Proximity Switch/PLC Compatibility specifications are:

U_s = Supply voltage
U_{off} = Maximum voltage for a PLC input OFF-state
U_{on} = Minimum voltage for a PLC input ON-state
I_{off} = Maximum current for a PLC input OFF-state

Table C-1
Proximity Switch/PLC Compatibility Specifications

PLC Input type volts	I_r 2 wire mA	I_{off} PLC mA	I_r 3 or 4 wire mA	I_m 2 wire mA	I_{on} PLC mA	I_m 3 or 4 wire mA	U_d 2 wire volts	U_d 3 or 4 wire volts	U_{on} PLC input volts	U_{off} PLC input volts
24 V DC	1.5		0.5	2		1	8 V DC	3.5 V DC	10 V DC	10/5* V DC
48 V DC	1.5		0.5	2		1	8 V DC	3.5 V DC	30 V DC	30/10* V DC
24 V AC	2		0.5	5		1	10 V AC	3.5 V AC	10 V AC	10/5* V AC
48 V AC	2		0.5	5		1	10 V AC	3.5 V AC	30 V AC	30/10* V AC
120 V AC	2.5		0.5	5		1	10 V AC	3.5 V AC	79 V AC	79/20* V AC
240 V AC	2.5		0.5	5		1	10 V AC	3.5 V AC	164 V AC	164/40* V AC

* Proximity switches which generate a supply impulse current may instantaneously exceed I_{off} during a PLC input OFF-state. If this occurs, and the resulting PLC input voltage drop remains below U_{off}*, the PLC input will maintain the OFF-state.

NOTE – All values are true rms

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C-2 ON-State Requirements

The PLC input is in an ON-state if:

$(U_s - U_d) \geq U_{on}$ and $I \geq I_{min}$

where:

U_s = Supply voltage
U_d = Maximum Voltage Drop across the energized output of the proximity switch.
U_{on} = Minimum Voltage to assure "ON State" of the PLC.
I_m = minimum supply current required by a proximity sensor to maintain an ON-state

The current vs. voltage ON-state region is described in Figure C-1.

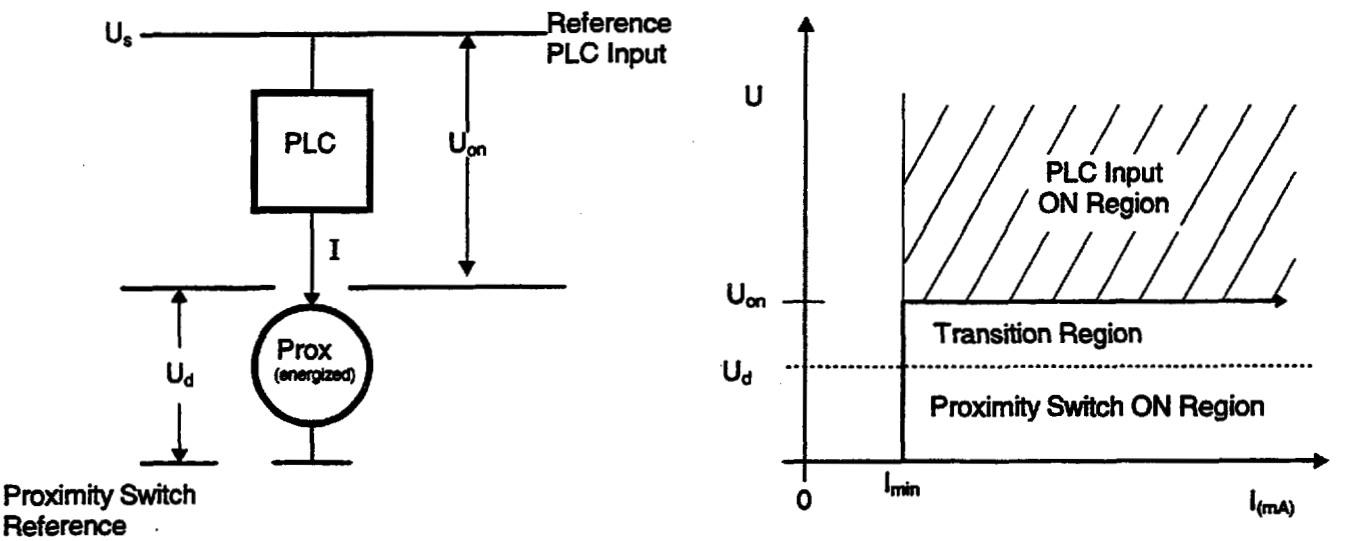


Figure C-1
PLC ON-state requirements

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>-3 OFF-State Requirements

The PLC is in the OFF-state if:

$$I \le I_{off} \text{ and } (U_s - U_{b\,min}) \le U_{off}$$

where:

I_{off} = Maximum permissible current for a PLC input OFF-State
I = Current
U_s = Supply voltage
$U_{b\,min}$ = Minimum Voltage Drop across the de-energized output of the proximity switch.
U_{off} = Maximum Voltage to possible to assure OFF-State of the PLC input.

The current vs. voltage OFF-state region is described in Figure C-2.

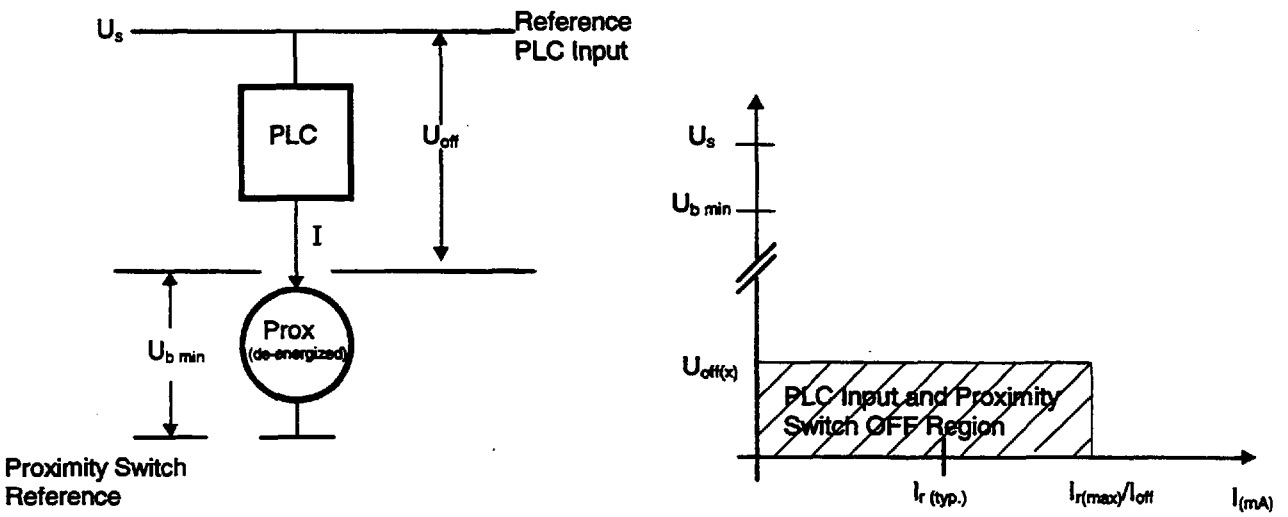


Figure C-2
PLC OFF-state requirements

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