

INDUSTRIAL CONTROL BASICS:

Part 4 - Pilot Devices for Indication & Actuation



Introduction

Pilot devices are mainly used in the commercial or industrial applications where human-to-machine interface is required. These comprise various types of selector switches, pushbuttons, pilot lights, signal beacons, as well as toggle switches. Based on their designs, pilot devices can be distinguished into two types: indication devices and actuation devices. And some devices provide both indication and actuation (ex: illuminated pushbuttons).

Typically used as a part of a system, automated process, or a control panel, these devices provide information on condition and control monitoring of different types of processes, machinery, and equipment.

Types of Pilot Devices

1. Pushbuttons

These are the control devices used to manually close and open a set of contacts. Pushbuttons are available with a variety of operator designs such as flush, extended, or mushroom head, with or without illumination. These devices are usually provided with normally closed, normally open, or combination contact blocks.

2. Pilot Lights

As the name suggests, these devices provide the visual indication about the operating status of a circuit. They are mainly used for ON/OFF indication, changing conditions, and alarm signaling.

Pilot lights are also available in a variety of designs such as:

- **Indicator:** Equipped with incandescent lamps or LED's, these lights are mainly used as indicating lights in automated instruments, condition panels, telephones, and dashboards.
- **Relampable:** These pilot lights feature a lens that can be replaced from the front panel of the lighted device in the indicator, once they stop functioning.
- **Non-Relampable:** As the name suggests, these lights are offered as one-piece device with fixed lens. It means the whole indicator need to be replaced, if the lighted device stops functioning.

Pilot lights include a colored lens such as red, green, blue, yellow/amber, clear, or white. These colored lenses symbolize the condition of the machine or equipment to which the lights are connected.

3. Selector Switches

These rotary devices are used to close or open contacts manually. Typically available in designs such as spring return, maintained, or key operated types, selector switches differ from pushbuttons only in their operation. The selector switches feature levers or knobs that are rotated to open or close the contacts, whereas pushbuttons operate linearly and have buttons for performing the same task. The contact blocks on the selector switches are typically interchangeable with those on the pushbuttons. These switches can be easily used to select one or multiple possibilities such as hand-off-automatic, high or low speed, run or stop, and up or down. Selector switches are available in two-, three-, or four-position types.

4. Emergency Stops

Designed to improve the safety of equipment and workers, these pilot devices are required by installation codes and standards, and are used to disable a machine or a system in the event of an emergency. Often referred to as emergency stop pushbuttons, these devices are mainly of two types: push-pull, and push-twist release.

5. Potentiometers

These devices feature three-terminal resistors with rotating or sliding contacts, which adjust the voltage sent to the machine.

Ranges of Pilot Devices

In the US, pilot devices are mainly categorized as modular or compact/monolithic based on their construction.

- **Modular:** These devices are designed such that each individual component can be selected and configured for a special purpose. Modular pilot devices enable pre-wiring, and are customizable, and flexible. They can be easily used in industrial environments, and are often designed to comply with UL Type ratings 1, 3, 3R, 4, 4X, 12, and 13. The most common sizes are 30 mm and 22 mm.
- **Compact/Monolithic:** These devices help OEMs save space and streamline their operational costs. Featuring all-in-one designs, these compact devices have limited functionalities. Unlike modular designs, compact pilot devices do not allow the flexibility of multiple configurations, and have unique part numbers.

Terminology of Pilot and Actuation Devices

Term	Definition
Actuator/Operator	The mechanical piece of the device that is touched to operate other contacts in the device. These include the pushbutton caps, pilot light lens, and selector switch knobs.
Contact	It is a conducting part in the contact block that connects with other conducting parts to make and break a circuit. There are two states, "normally open" and "normally closed". In the unactuated "normally open" state, the circuit is open. In the unactuated "normally closed" state the circuit is closed. The unactuated state of the contact can be changed by operating the pushbutton or selector switch.
Contact Block	It is a housing that encapsulates the contacts, wiring terminals, and an actuating plunger. The contact blocks are normally held on the operator using a contact block holder or latch.
Debouncing	Electrical contacts in mechanical switches such as pushbutton switches make and break the contact several times on pushing the button. They produce multiple signals during this time. Debouncing is an act of removing the multiple signals to ensure that only one signal will be acted upon for a single closing or opening of the contact.
Light Module	A part of the pilot device that holds the light bulb. Indication occurs when the light module gets an appropriate signal (voltage).
Latch	A switch that once triggered on stays on until the power that goes into is removed or disabled. Unlike other switches, which operate only when pressed, latches remain actuated even after the button which triggers it is released.
Maintained	Contacts stay in the operating condition when they are actuated.
Momentary	Contacts return to their original position post-actuation.
Pole	This refers to number of circuits controlled by the switch.
Rated Enclosed Thermal Current	The value of the conventional enclosed thermal current shall be at least equal to the maximum value of the rated operational current of the enclosed equipment in an 8-hour duty.
Rated Operational Current	Takes into account the rated operational voltage, the rated frequency, the rated duty, the utilization category, and the type of protective enclosure if appropriate.
Throw	This refers to the number of closed contact positions in a pole. In single throw, the pole has one closed contact position. In double throw, the pole has two closed contact positions.

Pilot Device Colors, Meanings and Functions

Push Button Colors:

Color Coding for Push Button Actuators and Their Meanings			
Color	Meaning	Explanation	Examples of Application
RED	Emergency	Actuate in the event of a hazardous condition or emergency	Emergency Stop Initiation of emergency function
YELLOW	Abnormal	Actuate in the event of an abnormal condition	Intervention to suppress abnormal condition Intervention to restart an interrupted automatic cycle
GREEN	Normal	Actuate to initiate normal conditions	(see following table)
BLUE	Mandatory	Actuate for a condition requiring mandatory action	Reset function
WHITE	No specific meaning assigned	For general initiation of functions except for emergency stop (see note)	START/ON (preferred) STOP/OFF
GREY			START/ON STOP/OFF
BLACK			START/ON STOP/OFF (preferred)

NOTE: Where a supplemental means of coding (e.g. shape, position, texture) is used for the identification of push button actuators, then the same color WHITE, GREY, or BLACK may be used for various functions (e.g. WHITE for START/ON and for STOP/OFF actuators).

Colors of Typical Push Button Operators, by Function					
Actuator Function	Shall Be Used	Should Be Used	Preferred Color	Permitted Color	Shall Not Be Used
START/ON	—	White, Grey, or Black	White	Green	Red
Emergency Stop and Emergency Switching OFF	Red	—	—	—	—
STOP/OFF	—	Black, Grey, or White	Black	Red	Green
Push Button Actuators that alternately act as START/ON and STOP/OFF	—	—	White, Grey, or Black	—	Red, Yellow, or Green
Push Button Actuators that cause operation while they are actuated and cease the operation when they are released (ex. Hold-to-Run)	—	—	White, Grey, or Black	—	Red, Yellow, or Green
Reset Push Buttons	Blue, White, Grey, or Black	—	—	—	Green
Reset Push Buttons that also act as a STOP/OFF button	—	Blue, White, Grey, or Black	Black	—	Green

Source: IEC 60204-1, Safety of Machinery, Electrical Equipment of Machines, Part 1 General Rules

Push Button Colors (cont.):

Colors of Typical Push Button Operators, by Function					
Actuator Function	Shall Be Used	Should Be Used	Preferred Color	Permitted Color	Shall Not Be Used
START/ON	—	—	Green	White, Grey, or Black	Red
Emergency Stop	Red	—	—	—	—
STOP/OFF	—	—	Red	White, Grey, or Black	Green
Push Button Actuators that alternately act as START/ON and STOP/OFF	White, Grey, or Black	—	—	—	Red, Yellow, or Green
Push Buttons used to respond to abnormal conditions	Yellow	—	—	—	—
Push Button Actuators that cause operation while they are actuated and cease the operation when they are released (ex. Jogging)	White, Grey, Blue, or Black	—	Black	—	—
Reset Push Buttons	Blue, White, Grey, or Black	—	—	—	Green
Reset Push Buttons that also act as a STOP/OFF button	Red	—	—	—	—

Source: NFPA 79 Electrical Standard for Industrial Machinery

Indicator Light Colors:

Indicator lights and displays serve to give the following types of information:

- Indication – to attract the operator's attention or to indicate that a certain task should be performed. The colors RED, YELLOW, GREEN, and BLUE are normally used in this mode.
- Confirmation – to confirm a command, or a condition, or to confirm the termination of a change or transition period. The colors BLUE and WHITE are normally used in the mode and GREEN may be used in some cases.
- Unless otherwise agreed to between the supplier and user, indicator (pilot) light lenses shall be color-coded with respect to the condition (status) of the machine in accordance with the following table.

Colors for Indicator Lights and Their Meanings with Respect to the Condition of the Machine			
Color	Meaning	Explanation	Action by Operator
RED	Emergency	Hazardous condition	Immediate action to deal with hazardous condition (e.g. by operating emergency stop)
YELLOW	Abnormal	Abnormal condition Impending critical condition	Monitoring and/or intervention (e.g. by re-establishing the intended function)
GREEN	Normal	Normal condition	Optional
BLUE	Mandatory	Indication of a condition that requires action by the operator	Mandatory action
WHITE	Neutral	Other conditions; may be used whenever doubt exists about the application of RED, YELLOW, GREEN, BLUE	Monitoring

NOTE: Alternative meanings to those defined in the preceding table may be assigned in accordance with one of the following criteria: the safety of persons and the environment, and the state of the electrical equipment.



Source: ©International Electrotechnical Commission

Indicator Light Colors (cont.) :

Machine Indicator Lights			
Color	Safety of Persons or Environment	Condition of Process	State of Equipment
RED	Danger	Emergency	Faulty
YELLOW (AMBER)	Warning/Caution	Abnormal	Abnormal
GREEN	Safe	Normal	Normal
BLUE	Mandatory Action	Mandatory Action	Mandatory Action
CLEAR WHITE GREY BLACK	No specific meaning assigned	No specific meaning assigned	No specific meaning assigned

Source: NFPA 79 Electrical Standard for Industrial Machinery

NEMA, UL and CSA Enclosure Ratings



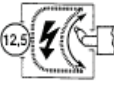
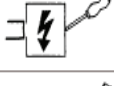



Enclosure Types Non-Hazardous Location			
Enclosure Rating	NEMA National Electrical Manufacturers Association (NEMA Standard 250) and Electrical and Electronic Mfg. Association of Canada (EEMAC)	 Underwriters Laboratories Inc. (UL50 and UL508)	 Canadian Standards Association (Standard C22.2 No. 94)
Type 1	Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.	Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dust.	General purpose enclosure. Protects against accidental contact with live parts.
Type 3	Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow, and wind-blown dust; undamaged by the external formation of ice on the enclosure.
Type 3R*	Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain and snow; undamaged by the external formation of ice on the enclosure.
Type 4	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, and hose directed water; undamaged by the formation of ice on the enclosure.	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure.
Type 4X	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, wind-blown dust and rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure.	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure; resists corrosion.	Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure; resists corrosion.
Type 6	Enclosures are intended for use indoors or outdoors where occasional submersion is encountered, limited depth, undamaged by the formation of ice on the enclosure.	Indoor or outdoor use to provide a degree of protection against entry of water during temporary submersion at a limited depth; undamaged by the external formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against the entry of water during temporary submersion at a limited depth. Undamaged by the external formation of ice on the enclosure; resists corrosion.
Type 12	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dripping non-corrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water, and external condensation of non-corrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers, and flyings; dripping and light splashing of non-corrosive liquids; not provided with knockouts.
Type 12K	Enclosures with knockouts are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dropping non-corrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water, and external condensation of non-corrosive liquids. Knockouts located in the top or bottom walls, or both.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of non-corrosive liquids; provided with knockouts.
Type 13	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and non-corrosive coolant.	Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil, and non-corrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers, and flyings; seepage and spraying of non-corrosive liquids, including oils and coolants.

*NFPA 70 (National Electric Code) defines new Type 3RX as providing the same degree of protection as Type 3R, with the addition of protection against corrosive agents.










Source: NEMA, UL and CSA Standards.

IEC Enclosure Ingress Protection (IP) Ratings





The IEC, standard 60529 defines Ingress Protection with a two digit code. The first digit describes the degree of protection against access to hazardous parts and ingress of solid objects. The second digit designates the Ingress Protection against water. Please refer to the appropriate sections of IEC 60529 for complete information regarding applications, features, and design tests.

First Numeral			
Protection Against Ingress of Solid Objects			Protection of Persons Against Access to Hazardous Parts with:
IP	Requirements	Example	
0	No protection.		Non-Protected
1	Full penetration of 50mm diameter sphere not allowed. Contact with hazardous parts not permitted.		Back of Hand
2	Full penetration of 12.5mm diameter sphere not allowed. The jointed test finger shall have adequate clearance from hazardous parts.		Finger
3	The access probe of 2.5mm diameter shall not penetrate.		Tool
4	The access probe of 1.0mm diameter shall not penetrate.		Wire
5	Limited ingress of dust permitted (no harmful deposit).		Wire
6	Totally protected against ingress of dust.		Wire

Source: ©International Electrotechnical Commission

Second Numeral			
Protection Against Harmful Ingress of Water			Protection from Water:
IP	Requirements	Example	
0	No protection.		Non-Protected
1	Protected against vertically falling drops of water. Limited ingress permitted.		Vertically Dripping
2	Protected against vertically falling drops of water with enclosure tilted 15° from the vertical. Limited ingress permitted.		Dripping up to 15° from the Vertical
3	Protected against sprays to 60° from the vertical. Limited ingress permitted.		Limited Spraying
4	Protected against water splashed from all directions. Limited ingress permitted.		Splashing from all Directions
5	Protected against jets of water. Limited ingress permitted.		Hosing Jets from all Directions
6	Protected against strong jets of water. Limited ingress permitted.		Strong Hosing Jets from all Directions
7	Protected against the effects of immersion between 15cm and 1m.		Temporary Immersion
8	Protected against long periods of immersion under pressure.		Continuous Immersion

Source: ©International Electrotechnical Commission

Additional Letter (Optional)			
Protection Against Ingress of Solid Objects			Protection of Persons Against Access to Hazardous Parts with:
IP	Requirements	Example	
A (For use with first numeral 0)	Penetration of 50mm diameter sphere up to barrier must not contact hazardous parts.		Back of Hand
B (For use with first numerals 0 and 1)	Test finger penetration to a maximum of 80mm must not contact hazardous parts.		Finger
C (For use with first numerals 1 and 2)	Wire of 2.5mm diameter x 10mm long must not contact hazardous parts when spherical stop face is partially entered.		Tool
D (For use with first numerals 2 and 3)	Wire of 1.0mm diameter x 100mm long must not contact hazardous parts when spherical stop face is partially entered.		Wire

Source: ©International Electrotechnical Commission

NEMA ENCLOSURE TYPE RATINGS / IEC ENCLOSURE IP RATINGS

CONVERSION OF NEMA ENCLOSURE TYPE RATINGS TO IEC 60529 ENCLOSURE CLASSIFICATION DESIGNATIONS (IP) (CANNOT BE USED TO CONVERT IEC CLASSIFICATION DESIGNATIONS TO NEMA TYPE RATINGS)

CONVERSION OF NEMA ENCLOSURE TYPE RATINGS TO IEC 60529 ENCLOSURE CLASSIFICATION DESIGNATIONS (IP) (CANNOT BE USED TO CONVERT IEC CLASSIFICATION DESIGNATIONS TO NEMA TYPE RATINGS)														
IP FIRST CHARACTER	NEMA ENCLOSURE TYPE													IP SECOND CHARACTER
	1	2	3	3R	3S	4	4X	5	6	6P	12	12K	13	
IP0_														IP_0
IP1_														IP_1
IP2_														IP_2
IP3_														IP_3
IP4_														IP_4
IP5_														IP_5
IP6_														IP_6
														IP_7
														IP_8
	A	B	A	B	A	B	A	B	A	B	A	B	A	B

A = A shaded block in the "A" column indicates that the NEMA Enclosure Type exceeds the requirements for the respective IEC 60529 IP First Character Designation.

The IP First Character Designation is the protection against access to hazardous parts and solid foreign objects.

B = A shaded block in the "B" column indicates that the NEMA Enclosure Type exceeds the requirements for the respective IEC 60529 IP Second Character Designation.

The IP Second Character Designation is the protection against the ingress of water.

Examples of Table Use:

An IEC IP45 Enclosure Rating is specified. What NEMA Type Enclosures meet and exceed the IP45 rating?

Referencing the first character, 4, in the IP rating and the row designated "IP4_" in the leftmost column in the table; the blocks in Column "A" for NEMA Types 3, 3S, 4, 4X, 5, 6, 6P, 12, 12K and 13 are shaded. These NEMA ratings meet and exceed the IEC protection requirements against access to hazardous parts and solid foreign objects. Referencing the second character, 5, in the IP rating and the row designated "IP_5" in the rightmost column in the table; the blocks in Column "B" for NEMA Type 3, 3S, 4, 4X, 6 and 6P are shaded. These NEMA ratings meet and exceed the IEC requirements for protection against the ingress of water. The absence of shading in Column "B" beneath the "NEMA Enclosure Type 5" indicates that Type 5 does not meet the IP45 protection requirements against the ingress of water. Likewise, the absence of shading Column "B" for NEMA Type 12, 12K and 13 enclosures indicates that these enclosures do not meet the IP45 requirements for protection against the ingress of water. Only Type 3, 3S, 4, 4X, 6 and 6P have both Column "A" in the "IP4_" row and Column "B" in the "IP_5" row shaded and could be used in an IP45 application.

The NEMA Enclosure Type 3 not only meets the IP45 Enclosure Rating, but also exceeds the IEC requirements because the NEMA Type requires an outdoor corrosion test; a gasket aging test; a dust test; an external icing test; and no water penetration in the rain test. Slight differences exist between the IEC and NEMA test methods, but the IEC rating permits the penetration of water if "it does not deposit on insulation parts, or reach live parts." The IEC rating does not require a corrosion test; gasket aging test; dust test or external icing test. Because the NEMA ratings include additional test requirements, this table cannot be used to select IP Designations for NEMA rated enclosure specifications.

IEC 60529 specifies that an enclosure shall only be designated with a stated degree of protection indicated by the first characteristic numeral if it also complies with all lower degrees of protection. Furthermore, IEC 60529 states that an enclosure shall only be designated with a degree of protection indicated by the second characteristic numeral if it also complies with all lower degrees of protection up to and including the second characteristic numeral 6. An enclosure designated with a second characteristic numeral 7 or 8 only is considered unsuitable for exposure to water jets (designated by second characteristic numeral 5 or 6) and need not comply with requirements for numeral 5 or 6 unless it is dual coded. Since the IEC protection requirements become more stringent with increasing IP character value up through 6, once a NEMA Type rating meets the requirements for an IP designation up through 6, it will also meet the requirements for all lower IP designations. This is apparent from the shaded areas shown in the table.

Source: ©National Electrical Manufacturers Association

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