Limit Switches

Proper Application of Limit Switches
General Information

Limit switches are used to convert a mechanical motion into an electrical control signal. The mechanical motion is usually in the form of a cam, a machine component or an object moving toward a predetermined position. The cam engages the limit switch lever or plunger and this in turn makes or breaks an electrical contact inside the switch. This electrical control signal is then used to limit position or reverse the machine travel, or to initiate another operating sequence. It can also be used for counting, sorting or as a safety device.

Typical limit switch applications are in the control circuits of solenoids, control relays and motor starters which control the motion of machine tools, conveyors, hoists, elevators and practically every type of motor driven machine.

Experience has shown that most limit switch failures are the fault of the installation. In some cases an installation that is not perfect cannot be avoided, but in the majority of cases, proper application of the limit switch would have prevented failure. For application assistance, call 1-800-NAMTECH.

Definition of Limit Switch Terms

Actuator - Mechanism of the switch or switch enclosure which operates the contacts, i.e. lever arm, plunger, wobble stick.

Break - To open an electrical circuit.

Cam - Machine part or component that applies force to switch actuator causing actuator to move as intended. See also “Dog.”

Cam Track - Distance from switch mounting surface to a specified point on actuator.

Differential Travel - Distance or angle from the operating position to the reset position.

Direct-Acting Contacts - Contacts are moved directly by the operating shaft. In general should only be used where movement of actuator must break welded contacts, as in a crane safety limit switch.

Dog - Machine part or component that applies force to switch actuator causing actuator to move as intended. See also “Cam.”

Double Break - Contacts open circuit at two points.

Double Pole Double Throw (DPDT) - Switches which make and break two separate circuits. This circuit provides a normally open and normally closed contact for each pole.

Free Position - Position of switch actuator when no external force (other than gravity) is applied on the actuator. See also “Initial Position” and “Normal Position.”

Initial Position - Position of switch actuator when no external force (other than gravity) is applied on the actuator. See also “Free Position” and “Normal Position.”

Maintained Contact Switch - Designed for applications requiring sustained contact after actuator has been released, but with provision for resetting.

Make - To close or establish an electrical circuit.

Momentary Contact Switch - A switch which returns from the operated condition to normal condition when actuating force is removed. See also “Spring Return.”

Neutral Position Limit Switch - Lever arm type switch with two sets of contacts, one of which operates when the shaft is rotated clockwise and the other of which operates when the shaft is rotated counter-clockwise.

Normal Position - Position of switch actuator when no external force (other than gravity) is applied to actuator. See also “Free Position” and “Initial Position.”

Normally Closed Contact (N.C.) - Contacts that move to the closed position when no external force is on the actuator.

Normally Open Contacts (N.O.) - Contacts that move to the open position when no external force is on the actuator.

Operating Force - Amount of force applied to the actuator to cause contact operation.

Operating Position - Position of the actuator at which the contacts move to the operated position. See also “Trip Position.”

Overtravel - Movement of the actuator beyond the operating position.

Pilot Duty Rating - Rating of contacts when making and breaking inductive loads such as coil and solenoids.

Pole - Parts necessary to control one conductor of a circuit.

Precision Snap Acting Switch - An electromechanical switch having predetermined and accurately controlled characteristics and having a spring loaded, quick make-and-break contact action.

Pretravel - Distance or angle through which the actuator moves from the normal position to the operating position.

Reset Position - Position of actuator at which contacts return to the normal position. See also “Releasing Position.”

Releasing Position - Position of actuator at which contacts return to the normal position. See also “Reset Position.”

Repeat Accuracy - Ability of a switch to repeat its characteristics precisely from one operation to the next operation. See also “Repeatability.”

Repeatability - Ability of a switch to repeat its characteristics precisely from one operation to the next operation. See also “Repeat Accuracy.”

Single Pole Double Throw (SPDT) - Switches which make and break one circuit. Circuit provides one normally open and one normally closed contact.

Slow Make-and-Break Contacts - The speed of contact transfer is directly dependent on the speed of the operating shaft.

Snap Action - 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.

Snap Back - Sudden return of actuator to normal position.

Spring Return Switch - A switch which returns from operated condition to normal condition when actuating force is removed. See also “Momentary Contact Switch.”

Trip Position - Position of the actuator at which the contacts move to the operated position. See also “Operating Position.”

Total Travel - Distance from actuator-free position to overtravel limit position.

Actuator Design

For maximum limit switch life, the force applied to the lever arm by a cam should be perpendicular to the lever arm. This means that the cam angle and lever arm angle should be the same.

A good recommended cam angle and lever arm angle at moderate cam speeds (up to 90 fpm) is 45°, see Figure 1-1. Here lever acceleration is less and deceleration is also less at the lower cam edge.

The arrangement shown in Figure 1-2 is satisfactory only at cam speeds below 50 fpm. At higher speeds, the impact due to high lever acceleration causes excess roller bounce. Rapid deceleration occurs at the lower cam edge.

The cam trailing edge on overriding cams must also be considered for maximum switch life, see Figure 1-3. Lever arm snap back causes shock loads which reduce switch life. Also, with reversing cams the trailing edge becomes a leading edge on the return stroke.

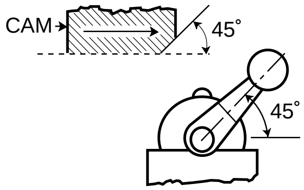


Figure 1.1
Recommended for moderate cam speeds - up to 90 fpm
Non-overriding cams

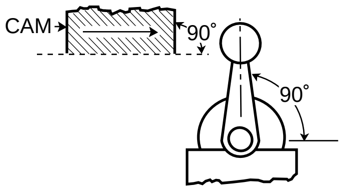


Figure 1.2
Satisfactory only for low cam speeds - 50 fpm or less
Non-overriding cams

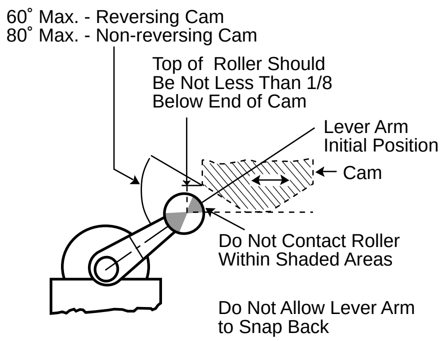


Figure 1.3
For overriding cams - up to 90 fpm

NAMCO
2013 West Meeting Street • Lancaster, SC 29720
1-803-286-8491 • FAX: 1-800-678-6263
www.namcocontrols.com

Electrical Ratings

RATINGS —

Many control applications involve high inductive loads such as starter, contactor and relay coils; solenoids and clutches. In order to apply a control device correctly, the inductive rating must be known. Ratings are generally listed in three ways:

1. Resistive or non-inductive.
2. Inductive (pilot duty).
3. Continuous.

Resistive or non-inductive ratings - This rating indicates the resistive load only that the contacts make or break. Resistive ratings are generally based on a 75% minimum power factor for AC.

Inductive (pilot duty) ratings - The inductive rating indicates the non-motor inductive load, such as the contactors, relays and other remotely controlled devices that the contacts can make or break. These ratings usually are based on a 35% power factor for AC.

Continuous rating - Continuous rating indicates the load that the contacts can carry continuously without making or breaking the circuit.

The inductive rating is always less than the resistive or continuous rating. When contacts break an inductive circuit, the inductance in the load tends to keep the current flowing in the same direction. The result is an arc across the contacts which causes heating and burning of the contacts. Because of the extra heat generated, the allowable inductive current must be less than the resistive current for equal contact life.

Quick make and quick break (snap-action) contacts reduce the arcing time and allow higher inductive ratings than with slow make-or-break contacts. AC inductive coil loads have a momentary inrush current of approximately 10 times the sealed current. Contacts must be able to break or interrupt the inrush current in an emergency.

Excessive load - If the load exceeds the ratings of the limit switch being used, a control relay (CR) or contactor with proper ratings can be used as in Figure 1-4.

The DC current ratings of a device can be increased by placing contacts in series. This effectively increases the contact gap allowing a higher current rating. In general, the following ratings can be applied:

2 contacts in series — DC rating x 2.5

3 contacts in series — DC rating x 5

Current should never exceed the maximum continuous current rating of the device.

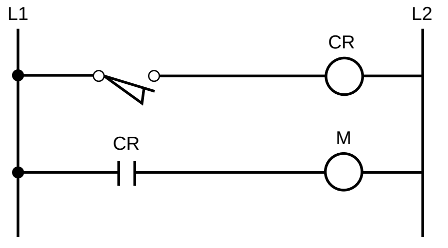


Figure 1.4

Contact Resistance

RESISTANCE OF SNAP SWITCHES

Snap switch resistance is the total electrical resistance that a snap switch adds to the circuit and consists of:

Conducting Path. Includes all terminals, inserts, stationary contact material resistance, movable contact material resistance, movable blade assembly, and any other parts in the conducting circuit.

Constriction Resistance of all joints, discontinuities, or interfaces. This is the resistance caused by limited mating surfaces through which the load must pass. If the movable and stationary contact tips are viewed through a microscope, it can be seen that they only touch at a very few points. Thus, increased resistance is presented to the current. If the current is high enough, the points of constriction are softened and enlarged through thermal effects and the resistance decreases.

Film resistance. It is well known that silver accumulates a surface resistance due to chemical reaction with its environment. The most common reaction is with sulfur and oxygen which creates a sulfide and an oxide of silver. Such a surface is known to have some resistance which can be read with a low voltage instrument such as an ohmmeter. These surfaces, however, have the characteristic of being self-clearing. When current is passed through such a surface, it creates heat which, in turn, reduces the compound to pure silver again and restores the contact to a low ohmic value. This has long been the characteristic which has made silver such a good selection for contact materials.

Standard contacts can be gold plated to reduce switch resistance, but may not provide sufficient increase in reliability to warrant the added cost. For example, if the contact material underneath is exposed at any point due to excessive current or normal mechanical wear, a contaminating film may develop and will eventually creep over the plated portion. Long-term reliability is then no better than with standard contacts.

Particle resistance. Contamination in the form of foreign material can also produce resistance. Carefully controlled production processes are used to prevent contamination during assembly of snap switches.

Namco limit switches are designed for use with industrial control equipment where voltages are relatively high — normally 120 volts or higher — and current levels are high — normally .25 amperes or higher. An increase in switch resistance may appear to be more critical in high energy circuits because it represents a greater percentage of total circuit impedance; however, the arcing produced breaks down or burns away the contaminants, reducing the actual resistance seen by the load.

Switch resistance in dry circuit (low voltage, low current) applications is more of a problem, but the resistance has to be quite high to significantly affect operation. For example, a solid state circuit operating at 20 volts and 1 ma has a circuit resistance of 20 divided by (1×10^{-3}) or 20,000 ohms. A Snap-Lock switch with 10 ohms resistance would have little effect. The problem arises with film or particle resistance which can be quite high or even present an open circuit. Use of snap switches with dry circuits is not recommended because these voltages and currents are not high enough to reduce the silver sulfide or silver oxide to pure silver or to burn away other contaminants present.

An ohmmeter test on Snap-Lock switches is unreliable because the most common voltage source in an ohmmeter is a 1.5 volt battery and to snap switch contacts being tested, this is just another dry circuit load. Several ohmmeter readings of the same contacts may vary from a few hundredths of an ohm to several ohms, yet the contacts will work perfectly with a nominal coil load.

Recommendations for Application and Testing of Limit Switch Contacts

Standard Namco limit switches are normally recommended for use with industrial control devices, not dry circuits. If lower voltages are present, the current drawn through the contacts should be on order of .25 amperes in order to maintain proper continuity.

To test continuity in the field, a six volt, .25 ampere pilot light is recommended.

Do not use an ohmmeter to test continuity.

An ohmmeter is a reliable test only if the snap switch is to be used with a dry circuit and, as stated above, this is normally not recommended.

NAMCO
2013 West Meeting Street • Lancaster, SC 29720
1-803-286-8491 • FAX: 1-800-678-6263
www.namcocontrols.com

Limit Switches

Wiring and Mounting

- Unless specifically designed for such service, limit switches SHOULD NOT BE submerged in or splashed with oils, coolants or other liquids. CONSULT FACTORY.
- Limit switches MUST NOT BE used in locations where temperature or atmospheric conditions are beyond those for which they have been specifically designed.
- Power from different sources MUST NOT BE connected to the contact of one limit switch unless specifically designed for such service.
- Limit switches MUST BE used within their contact ratings. Refer to switch label on cover for electrical ratings and the appropriate limit switch bulletin for acceptable environmental conditions in which the switch has been designed to function properly.
- 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.
- Limit switches SHOULD BE placed in locations where machining chips do not accumulate under normal operating conditions to avoid chip interference with the lever operation.
- Opposite polarities MUST NOT BE connected to the contacts of one limit switch unless the limit switch is specifically designed for such service.

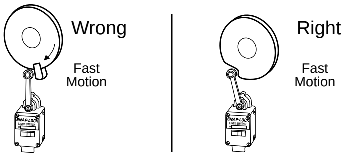
Limit Switch Selection

Selection of the proper electro-mechanical limit switch for an application generally breaks down into two major decisions, choosing the proper actuator (lever) and choosing the proper enclosure. There are other considerations, such as what operating sequences are available, temperature rating and electrical rating. These vary from switch type to switch type.

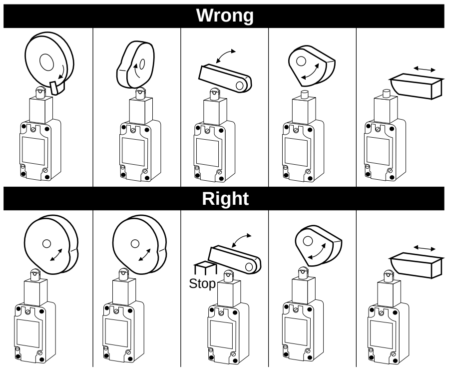
Selection of Limit Switch Actuator — Selection of a suitable actuator depends on the shape, speed, direction and total travel of the cam or part being used to trip the limit switch and the accuracy desired. See Operating Levers Section for levers offered fitting Namco limit switches.

Actuator Consideration

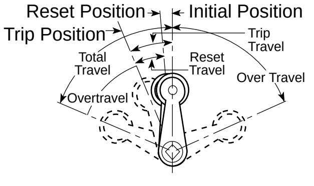
- Where relatively slow motions operate the limit switch, a snap-acting or snap-lock design SHOULD BE used.
- Where relatively fast motions are involved, cam arrangement SHOULD BE such that the actuator does not receive a severe impact.
- Where relatively fast motions are involved, cams MUST BE designed such that the limit switch will be held operated long enough to operate relays, valves, etc.



- For limit switches with pushrod actuators, the actuating force SHOULD BE applied as nearly as possible in line with the pushrod axis.

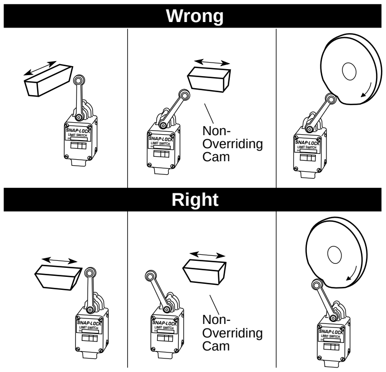


- Limit switches MUST NOT BE operated beyond the manufacturer's recommended travel. Operating positions and lever travel terminology are illustrated in drawing below. For specifications of a specific switch, refer to the switch bulletin.



NOTE: When loosening or tightening the pipe plug or set screw used to clamp the actuating lever in the desired position, care must be exercised to restrain the shaft/ lever assembly so as not to transmit the applied torque to the switch itself.

- Cam or dog arrangements SHOULD BE such that the actuator is not suddenly released to snap back freely unless specifically designed for such service.
- For limit switches with lever actuators, the actuating force SHOULD BE applied as nearly perpendicular to the lever as practical and perpendicular to the shaft axis in which the lever rotates.



- A limit switch actuator MUST BE allowed to move far enough for positive operation of the contacts.
- Limit switches MUST BE mounted in locations which will prevent false operation by normal movements of operator or machine components.
- Limit switches are designed for proper performance with the actuators with which they are supplied. Supplementary actuators SHOULD NOT BE used unless the limit switches are specifically designed for them.
- Operating mechanisms for limit switches MUST BE so designed that, under any operating or emergency conditions, the limit switch is not operated beyond its overtravel limit position. A limit switch MUST NOT BE used as a mechanical stop.

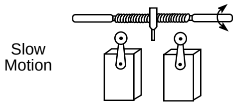
NAMCO
2013 West Meeting Street • Lancaster, SC 29720
1-803-286-8491 • FAX: 1-800-678-6263
www.namcocontrols.com

Cam Design

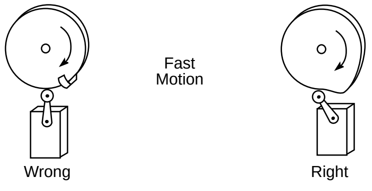
The most important consideration in the proper application of limit switches is external cam design. The majority of limit switch failures can be traced to poor cam design. Excessive overtravel and/or excessive snap back of the operating lever arm are the most common abuses. Good cam design will greatly increase the life of a limit switch.

Listed below are general rules for the proper design and application of limit switch cams published by NEMA in Standards Publication ICS2-225.

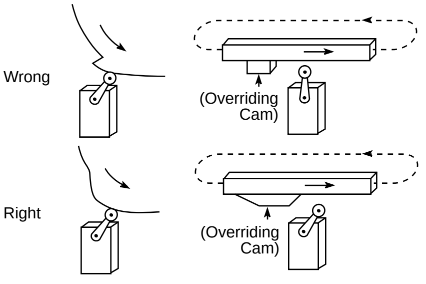
ICS2-225.83 - Where relatively slow motions operate the limit switch, it should generally be snap acting.



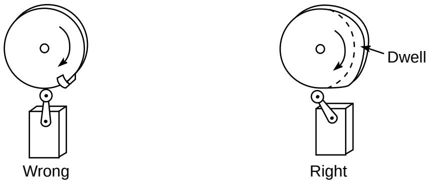
ICS2-225.84 - Where relatively fast motions are involved, cam arrangements should be such that the actuator does not receive a severe impact



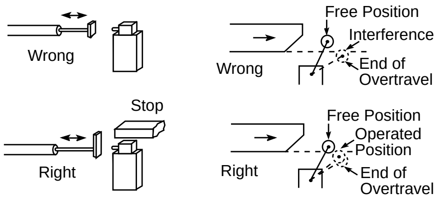
ICS2-225.85 - Cam or dog arrangements should be such that the actuator is not suddenly released to snap back freely.



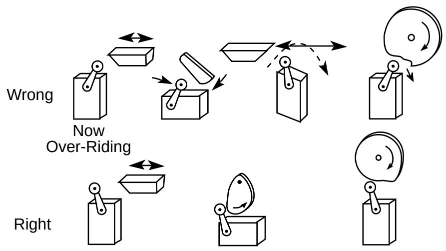
ICS2-225.86 - Where relatively fast motions are involved, cams should be designed such that the limit switch will be held operated long enough to operate relays, valves, etc.



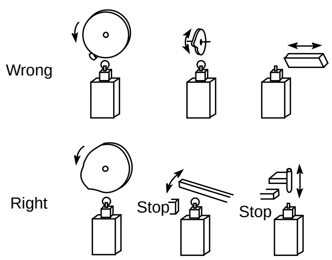
ICS2-225.88 - Operating mechanisms for limit switches should be so designed that under any operating or emergency conditions, the limit switch is not operated beyond its overtravel limit position. A limit switch should not be used as a mechanical stop.



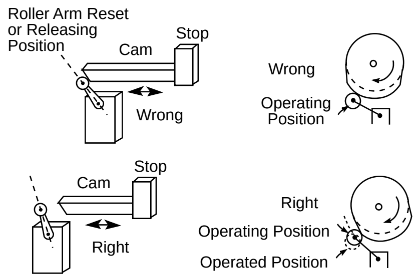
ICS2-225.90 - For limit switches with lever actuators, the actuating force should be applied as nearly perpendicular to the lever as practical, and perpendicular to the shaft axis about which the lever rotates.



ICS2-225.89 - For limit switches with pushrod actuators, the actuating force should be applied as nearly as possible in line with the push rod axis.



ICS2-225.91 - A limit switch actuator must be allowed to move far enough for positive operation of the contacts.



UL Listing of Namco Switches

The following is a list of all switches which are listed with Underwriters Laboratories:

File: E12967 Special Use Switches

Switch Marking: Underwriters Laboratory Inc. Recognized Snap Switch

Listed Switches: EA700-10000, -10001, -10100, -40000, -40001, -40100, -70000, -70001, -70100, -20000, -20001, -20100, -50000, -50001, 50100, -80000, -80001, -80100, -30000, -30001, -30100, -60000, -60001, -60100, -90000, -90001, -90100

File: E23331, Snap Switches for Use in Hazardous Locations

Switch Marking: Listed 921M

Listed Switches: EA800-10040, -10050, -10060, -10944, -10954, -10964, -20040, -20050, -20060, -20944, -20954, -20964, -30040, -30050, -30060, -30944, -30954, -30964

File: E59180, Industrial Control Equipment, Auxiliary Devices

Switch Marking: Listed Industrial Control EQ145M

Listed Switches: EA040-11105, EA040-21105, EA060-11105, EA060-21105, EA080-11105, EA080-21105

File: E62691, Industrial Control Equipment, Auxiliary Devices for use in Hazardous Locations

Switch Marking: Listed Industrial Control EQ for Haz Loc 727U

Listed Switches: EA880-11100, -11200, -11500, -11600, -12100, -12200, -12500, -12600, -13100, -13200, -13500, -13600

As presently produced, the EA170 and EA180 switches are not listed.

ICS 6-110.01 Definitions

Acid-resistant - Acid-resistant means so constructed that it will not be injured readily by exposure to acid fumes.
NEMA Standard 12-8-1972.

Dripproof - Dripproof means so constructed or protected that falling dirt or drops of liquid will not interfere with the successful operation of the apparatus under specified test conditions. See ICS 6-110.52.
NEMA Standard 7-16-1969.

Driptight - Driptight means so constructed or protected as to exclude falling dirt or drops of liquid under specified test conditions. See ICS 6-110.52.
NEMA Standard 7-16-1969.

Dusttight - Dusttight means so constructed as to meet the requirements of a specified dusttightness test. See ICS 6-110.54.
NEMA Standard 7-16-1969.

External Mounting - External mounting means enclosure mounting provisions external to the apparatus cavity.
NEMA Standard 7-16-1969.

Flush Mounting - Flush mounting means so designed as to have a minimal front projection when set into and secured to a flat surface.
NEMA Standard 7-16-1969.

Knockout - A knockout is a portion of the wall of a box or cabinet so fashioned that it may be removed readily by a hammer, screwdriver, and pliers at the time of installation in order to provide a hole for the attachment of a raceway cable or fitting.
NEMA Standard 7-16-1969.

Hazardous Locations - Hazardous locations are those areas which may contain hazardous materials in sufficient quantity to create an explosion. See Article 50 of the *National Electrical Code*.
NEMA Standard 7-16-1969.

Nonventilated - Nonventilated means so constructed as to provide no intentional circulation of external air through the enclosure.
NEMA Standard 7-16-1969.

Outdoor - Outdoor means suitable for installation where exposed to the weather.
NEMA Standard 7-16-1969.

Proof (Used as a Suffix) - Proof (used as a suffix) means so constructed, protected or treated that successful operation of the apparatus is not interfered with when subjected to the specified material or condition.
NEMA Standard 7-16-1969.

Rainproof - Rainproof means so constructed, protected or treated as to prevent rain under specified test conditions from interfering with successful operation of the apparatus. See ICS 6-110.53.
NEMA Standard 7-16-1969.

Raintight - Raintight means so constructed or protected as to exclude rain under specified test conditions. See ICS 6-110.53
NEMA Standard 7-16-1969.

Resistant (Used as a Suffix) - Resistant (used as a suffix) means so constructed, protected, or treated that the apparatus will not be damaged when subjected to the specified material or conditions for a specified time.
NEMA Standard 7-16-1969.

Sleetproof - Sleetproof means so constructed or protected that the accumulation of sleet (ice) under specified test conditions will not interfere with the successful operation of the apparatus including external operating mechanism(s). See ICS 6-110.55.
NEMA Standard 7-16-1969.

Sleet-resistant - Sleet-resistant means so constructed that the accumulation and melting of sleet (ice) under specified test conditions will not damage the apparatus. See ICS 6-110.55.
NEMA Standard 7-16-1969.

Submersible - Submersible means so constructed as to exclude water when submerged in water under specified test conditions of pressure and time.
NEMA Standard 7-16-1969.

Tight (Used as a Suffix) - Tight (used as a suffix) means so constructed that the enclosure will exclude the specified material under specified conditions.
NEMA Standard 7-16-1969.

Watertight - Watertight means so constructed as to exclude water applied in the form of a hose stream under specified test conditions. See ICS 6-110.56.
NEMA Standard 7-16-1969.

NAMCO

2013 West Meeting Street • Lancaster, SC 29720
1-803-286-8491 • FAX: 1-800-678-6263
www.namcocontrols.com