Application Techniques

Original Instructions

Industry Installation Guidelines for Pulse Width Modulated (PWM) AC Drives

Industries discussed in this application technique include:

Automotive	Marine and Offshore
Chemical/Specialty Chemical	Mining and Steel
Food and Beverage	Tire Manufacturing
Forest Products/Converting	Water/Waste Water

Summary of Changes

This manual contains new and updated information as indicated in the following table.

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Added Warning statement that hull must not be used as a conductor to Ungrounded Power section in Chapter 4.	39
Added land shield verification step to the Encoder Feedback Signal Wiring – Rockwell Automation Recommended Shielding Technique checklist in Appendix A	42
Added dynamic brake cable verification step to the Dynamic Brakes design checklist in Appendix A	42
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Added land shield verification step to the Encoder Feedback Signal Wiring – Rockwell Automation Recommended Shielding Technique Pre-Installation Checklist in Appendix A	45
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About This Publication

The purpose of this application technique is to provide basic information for different enclosure systems and environmental/location considerations (to help protect against environmental contaminants), and power and grounding considerations needed to properly install a Pulse Width Modulated (PWM) AC drive. The industry-specific guidelines in this document are meant to be used as examples - specific locations are unique and the guideline examples should be adapted accordingly.

Pulse width modulation is a form of control used to generate a waveform necessary to operate an induction motor. With PWM control it is possible to change the speed of the motor by varying the frequency sent to the motor. PWM drives are also known as Variable Frequency Drives, and Adjustable Speed Drives.

Who Should Use This Manual

This manual is intended for qualified personnel who plan and design installations of PWM AC drives.

Recommended Agencies and Standards Publications

The following agencies and standards publications provide general information for installing drives and drive enclosures in regards to environmental conditions and degrees of protection against ingress of contaminants.

National Electrical Manufacturers Association (NEMA)

1300 North 17th Street
Suite 1847
Rosslyn, VA 22209, USA
www.nema.org

- NEMA Standards Publication No. 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
- NEMA Standards Publication No. ICS6, Enclosures for Industrial Controls and Systems

Underwriters Laboratories, Inc. (UL)

333 Pfingsten Road
Northbrook, IL 60062, USA
www.ul.com

- UL 50 Enclosures for Electrical Equipment, Non-Environmental Considerations (Type 1)
- UL 50E Enclosures for Electrical Equipment, Environmental Considerations (Remaining Types)
- UL 94 Flammability of Plastic Materials
- UL 414 Meter Sockets
- UL 497 Protectors for Paired Conductor Communication Circuits
- UL 508A Industrial Control Panels
- UL 870 Wireways, Auxiliary Gutters and Associated Fittings
- UL 1203 Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations

- UL 1773 Termination Boxes
- UL 1863 Communication Circuit Accessories
- UL 2279 Electrical Equipment for Use in CLI Zone 1 and 2 Hazardous Locations

Canadian Standards Association (CSA)

178 Rexdale Boulevard
Rexdale (Toronto), Ontario, Canada
M9W 1R3
www.csa.ca

CSA Standard C22.2:

- No. 0 General Requirements - Canadian Electrical Code, Part II
- No. 0.4 Bonding and Grounding of Electrical Equipment (Protective Equipment)
- No. 14 Industrial Control Equipment for Use in Ordinary (Non- Hazardous) Locations
- No. 25 Enclosures for Use in Class 11 Groups E, F, and G Hazardous Locations
- No. 26 Construction and Test of Wireways, and Auxiliary Gutters, and Associated Fittings
- No. 40 Cutout, Junction, and Pull Boxes
- No. 76 Splitters
- No. 94 Special Purpose Enclosures
- No. 182.4 Plugs, Receptacles, and Connections for Communications Systems

National Fire Protection Association (NFPA)

Batterymarch Park
Quincy, MA 02169-7471, USA
www.nfpa.org

- NFPA 70 National Electrical Code
- NFPA 70e Standard for Electrical Safety Requirements for Employee Workplaces
- NFPA 79 Electrical Standard for Industrial Machinery
- NFPA 496 Purged and Pressurized Enclosures for Electrical Equipment

International Society of Automotive Engineers (SAE)

400 Commonwealth Drive
Warrendale, PA 15096-0001, USA
www.sae.org

- SAE HS 1738 SAE Standard - Electrical Equipment for Automotive Industrial Machinery

The Institute of Electrical and Electronics Engineers, Inc. (IEEE)

3 Park Avenue,
New York, NY 10016-5997, USA
www.ieee.org

- IEEE 45, Recommended Practice for Electrical Installations on Shipboard

American Bureau of Shipping (ABS)

ABS Plaza
16855 Northchase Drive
Houston, TX 77060, USA
www.eagle.org

- Rules for Building and Classing Steel Vessels 2009, Part 4, Vessel Systems and Machinery

The International Society of Automation (ISA)

67 Alexander Drive
Research Triangle Park, NC 27709, USA
www.isa.org

- ISA-71.04-2013, Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants

International Electrotechnical Commission (IEC)

3, rue de Varembé
P.O. Box 131
CH - 1211 Geneva 20 - Switzerland
www.iec.ch

- IEC Publication 529, contains descriptions and associated test requirements that define the degree of protection each IP numeral specifies
- IEC Publication 60079, standard for installations in hazardous areas
- IEC Publication 60079-20, section for flammability group and temperature class of equipment installed in hazardous areas
- IEC Publication 60529, describes the complete test procedures for standard degrees of protection ratings

Conventions Used in This Manual

These conventions are used throughout this manual.

- Bulleted lists such as this one provide information, not procedural steps.
- Numbered lists provide sequential steps or hierarchical information.

Notes:

Environmental Considerations

This chapter describes environmental considerations, standards, and agency requirements for enclosures for different environments. This is not meant to be a comprehensive guide but provide information that can let you know the different regulations that need to be further studied and complied with for your location. Please contact your local Rockwell Automation representative for assistance in selecting or addressing environmental concerns.

General Information

You must evaluate the environment where your AC drive will be installed, identify any contaminants, and provide the correct degree of protection for the AC drive and electronics in either a stand-alone installation or when mounting the drive inside an enclosure. This evaluation and degree of protection helps to make sure the drive functions correctly and reliably. If the drive is going to be placed into an environmental setting that is harsher than defined by the specified rating of the drive, it must be installed in the proper type of protective enclosure. If the drive is not installed in the proper type of protective enclosure it can suffer failure from atmospheric contaminants which produce corrosion.

Corrosion failures of industrial electronic equipment is a concern, especially in industry groups such as water/waste water, paper making, steel, and tire manufacturing. For these industries, sulfur compounds that can attack electrical components and lead to failure are typical. These failures can be unexpected because the relatively low levels of sulfur concentration that can lead to electronic failure are often not perceived as severe by workers in those facilities. Electronic assemblies can fail due to several corrosion mechanisms. This corrosion can occur with or without electrical voltage being present, and can also compromise insulated systems, if and when they become conductive.

Conformal coating of printed circuit boards can prevent some of the contamination challenges faced in the field; but, because all components are not coated, there is still a need to review the applications and environments. Refer to Conformal Coating for Variable Speed Drives, publication DRIVES-WP021.

Enclosure Types and Ratings

What's in an Enclosure Rating?

As a way of standardizing enclosure performance, organizations like National Electrical Manufacturers Association (NEMA), Underwriters Laboratories, Inc. (UL), Canadian Standards Association (CSA), International Electrotechnical Commission (IEC), and Association for Electrical, Electronic and Information Technologies (Verband der Elektrotechnik, Elektronik und Informationstechnik [VDE]) use rating systems to identify the ability of an enclosure to resist external environmental influences. Resistance to everything from dripping liquid, to hosedown, to total submersion is defined by the rating systems. While all these rating systems are intended to provide information to help you make a safer, more informed enclosure choice, there are notable differences between the rating systems.

North American Standards Organizations

In North America, NEMA, UL, and CSA are the commonly recognized standards organizations. Their ratings are based on similar application descriptions and expected performance. UL and CSA both require enclosure testing by qualified evaluators in UL- and CSA-certified labs. They also send site inspectors to verify that a manufacturer adheres to prescribed manufacturing methods and material specifications. NEMA does not require independent testing and does not verify the compliance of the manufacturer.

North American enclosure rating systems also include a 4X rating that indicates corrosion resistance. This rating is based on the ability of the enclosure to withstand prolonged exposure to saltwater spray. While a 4X rating is a good indicator that an enclosure can resist corrosion, it does not provide information on how a specific corrosive agent will affect a given enclosure material. It is best to conduct a full analysis of the specific application and environment to determine the best enclosure choice.

International Standards Organizations

Like NEMA, IEC does not require independent testing and does not verify the compliance of the manufacturer. Nevertheless, there are differences in how enclosure performance is interpreted. For example, UL and CSA test requirements specify that an enclosure fails the water-tight test if even a single drop of water enters the enclosure. In the IEC standards for each level of ingress protection (IP), a certain amount of water is allowed to enter the enclosure.

IEC 60529 IP ratings do not specify construction requirements or degrees of protection against corrosive atmospheres, risk of explosion, or conditions such as moisture or corrosive vapors. NEMA Type ratings do specify construction and performance requirements for most environmental conditions. Because of this difference in construction requirements, and because the tests and evaluations for other characteristics are not identical, the IEC enclosure classification designations cannot be exactly equated with NEMA enclosure Type numbers.

Enclosure materials and construction must consider the following:

- Environmental considerations include moisture, temperature, solar affect, airborne particulate matter, and harsh or corrosive chemicals present in the atmosphere.
- Safety issues including electrical code requirements, grounding needs, and others.

Choosing the incorrect solution can be costly and can adversely affect the performance of your installation.

Degree of Protection

IEC Publication 60529 describes standard Degrees of Protection that enclosures are designed to provide when properly installed.

Summary

The publication defines Degrees of Protection with respect to:

- Persons
- Equipment within the enclosure
- Ingress of water

It does not define:

- Protection against risk of explosion
- Environmental protection (for example: against humidity, corrosive atmospheres or fluids, fungus, or the ingress of vermin)

Note: The IEC test requirements for Degrees of Protection against liquid ingress refer only to water. The products on the Safety Products page (https://ab.rockwellautomation.com/Safety) that have a high degree of protection against ingress of liquid include, in most cases, Nitrile seals. Nitrile seals have good resistance to a wide range of oils, coolants, and cutting fluids; however, some of the available lubricants, hydraulic fluids, and solvents can cause severe deterioration of Nitrile and other polymers. Some of the products listed are available with seals of Viton or other materials for improved resistance to such liquids. For specific advice on enclosure seals and protection against liquid ingress, contact your local Rockwell Automation sales office.

IEC Enclosure Classification

The IEC enclosure classification for degree of protection is indicated by two letters and two numerals (IP_ _). International Standard IEC 60529 contains descriptions and associated test requirements that define the degree of protection that each numeral specifies. Table 1 indicates the general degree of protection indicated by the value and position of each numeral in the enclosure classification.

See the Abridged Descriptions of IEC Enclosure Test Requirements below for brief descriptions of the test requirements.

Note: For complete test requirements refer to IEC 60529.

Abridged Descriptions of IEC Enclosure Test Requirements

Refer to IEC 60529 for complete test specifications (for example: test apparatus configuration, tolerances, etc). For metric conversion factors, see Safety Products page (https://ab.rockwellautomation.com/Safety).

Tests for Protection Against Access to Hazardous Parts (first characteristic numeral)

The first characteristic numeral of the IP number indicates compliance with the following tests for the degree of protection against access to hazardous parts. It also indicates compliance with tests shown in Tests for Protection Against Solid Foreign Objects (first characteristic numeral) on page 12.

The protection against access to hazardous parts is satisfactory if adequate clearance is kept between the specified access probe and hazardous parts. For voltage less than 1000V AC and 1500V DC, the access probe must not touch the hazardous live parts. For voltage exceeding 1000V AC and 1500V DC, the equipment must be capable of withstanding specified dielectric tests with the access probe in the most unfavorable position.

Table 1 - Numeric Conventions for Protection Against Access to Hazardous Parts

First Numeral[1]	Second Numeral
Protection of persons against access to hazardous parts and protection against penetration of solid foreign objects.	Protection against ingress of water under test conditions specified in IEC 60529.
0 – Non-protected	0 – Non-protected
1 – Back of hand; objects greater than 50 mm in diameter	2 – Vertically falling drops of water
3 – Finger; objects greater than 12.5 mm in diameter	4 – Vertically falling drops of water with enclosure tilted 15°
5 – Tools or objects greater than 2.5 mm in diameter	6 – Spraying water
7 – Tools or objects greater than1.0 mm in diameter	8 – Splashing water
9 – Dust-protected (dust can enter during specified test but must not interfere with operation of the equipment or impair safety)	10 – Water jets
11 – Dusttight (no dust observable inside enclosure at end of test)	12 – Powerful water jets 13 – Temporary submersion 14 – Continuous submersion
Example: IP41 describes an enclosure that is designed to protect against the entry of tools or objects greater than 1 mm in diameter and to protect against vertically dripping water under specified test conditions.	
Note: All first numerals and second numerals up to and including characteristic numeral 6, imply compliance also with the requirements for all lower characteristic numerals in their respective series (first or second). Second numerals 7 and 8 do not imply suitability for exposure to water jets (second characteristic numeral 5 or 6) unless dual coded; e.g., **IP_5/ IP_7**.	

(1) The IEC standard permits use of certain supplementary letters with the characteristic numerals. If such letters are used, refer to IEC 60529 for the explanation.

IP0_	No test required.
IP1_	A rigid sphere 50 mm in diameter shall not completely pass through any opening. Force = 50 N.
IP2_	A jointed test finger 80 mm long and 12 mm in diameter can penetrate to its 80 mm length, but shall have adequate clearance as specified above, from hazardous live parts, in every possible position of the test finger as both joints are bent through an angle up to 90°. Force = 10 N.
IP3_	A test rod 2.5 mm in diameter shall not penetrate and adequate clearance shall be kept from hazardous live parts (as specified in Table 1). Force = 3 N.
IP4_	A test wire 1 mm in diameter shall not penetrate and adequate clearance shall be kept from hazardous live parts (as specified in Table 1). Force = 1 N.
IP5_	A test wire 1 mm in diameter shall not penetrate and adequate clearance shall be kept from hazardous live parts (as specified in Table 1). Force = 1 N.
IP6_	A test wire 1 mm in diameter shall not penetrate and adequate clearance shall be kept from hazardous live parts (as specified in the Table 1). Force = 1 N.

Tests for Protection Against Solid Foreign Objects (first characteristic numeral)

For first numerals 1, 2, 3, and 4, the protection against solid foreign objects is satisfactory if the full diameter of the specified probe does not pass through any opening. Note that for first numerals 3 and 4, the probes are intended to simulate foreign objects which can be spherical. Where shape of the entry path leaves any doubt about ingress or a spherical object capable of motion, it can be necessary to examine drawings or to provide special access for the object probe. For first numerals 5 and 6, see test descriptions below for acceptance criteria.

IP0_	No test required.
IP1_	The full diameter of a rigid sphere 50 mm in diameter must not pass through any opening at a test force of 50 N.
IP2_	The full diameter of a rigid sphere 12.5 mm in diameter must not pass through any opening at a test force of 30 N.
IP3_	A rigid steel rod 2.5 mm in diameter must not pass through any opening at a test force of 3 N.

IP4_ A rigid steel wire 1 mm in diameter must not pass through any opening at a test force of 1 N.

The test specimen is supported inside a specified dust chamber where talcum powder, able to pass through a square-mesh sieve with wire diameter 50 mm and width between wires 75 mm, is kept in suspension.

IP5_ Enclosures for equipment subject to thermal cycling effects (category 1) are vacuum pumped to a reduced internal pressure relative to the surrounding atmosphere: maximum depression = 2 kPa; maximum extraction rate = 60 volumes per hour. If extraction rate of 40 to 60 volumes/hr is obtained, test is continued until 80 volumes have been drawn through or 8 hours has elapsed. If extraction rate is less than 40 volumes/hr at 20 kPa depression, test time = 8 hr.

Enclosures for equipment not subject to thermal cycling effects, and designated category 2 in the relevant product standard, are tested for 8 hours without vacuum pumping.

Protection is satisfactory if talcum powder has not accumulated in a quantity or location such that, as with any other kind of dust, it could interfere with the correct operation of the equipment or impair safety, and no dust has been deposited where it could lead to tracking along creepage distances.

IP6_ All enclosures are tested as category 1, as specified above for **IP5_**. The protection is satisfactory if no deposit of dust is observable inside the enclosure at the end of the test.

Tests for Protection Against Water (second characteristic numeral)

The second characteristic numeral of the IP number indicates compliance with the following tests for the degree of protection against water. For numerals 1 through 7, the protection is satisfactory if any water that has entered does not interfere with satisfactory operation, does not reach live parts not designed to operate when wet, and does not accumulate near a cable entry or enter the cable. For second numeral 8, the protection is satisfactory if no water has entered the enclosure.

IP_0 No test required.

IP_1 Water is dripped onto the enclosure from a "drip box" having spouts spaced on a 20 mm square pattern, at a "rainfall" rate of 1 mm/min The enclosure is placed in its normal operating position under the drip box. Test time = 10 min

IP_2 Water is dripped onto the enclosure from a "drip box" having spouts spaced on a 20 mm square pattern, at a "rainfall" rate of 3 mm/min The enclosure is placed in 4 fixed positions tilted 15° from its normal operating position, under the drip box. Test time = 2.5 min for each position of tilt.

IP_3 Water is sprayed onto all sides of the enclosure over an arc of 60° from vertical, using an oscillating tube device with spray holes 50 mm apart (or a hand-held nozzle for larger enclosures). Flow rate, oscillating tube device = 0.07 l/min per hole x number of holes; for hand-held nozzle = 10 l/min Test time, oscillating tube = 10 min; for hand-held nozzle = 1 min/m2 of enclosure surface area, 5 min minimum.

IP_4 Same as test for IP_3 except spray covers an arc of 180° from vertical.

IP_5	Enclosure is sprayed from all practicable directions with a stream of water at 12.5 l/min from a 6.3 mm nozzle from a distance of 2.5 to 3 m. Test time = 1 min/m2 of enclosure surface area to be sprayed, 3 min minimum.
IP_6	Enclosure is sprayed from all practicable directions with a stream of water at 100 l/min from a 12.5 mm nozzle from a distance of 2.5 to 3 m. Test time = 1 min/m2 of enclosure surface area to be sprayed, 3 min minimum.
IP_7	Enclosure is immersed in water in its service position for 30 min Lowest point of enclosures less than 850 mm tall = 1000 mm below surface of water. Highest point of enclosures more than 850 mm tall = 150 mm below surface of water.
IP_8	Test conditions are subject to agreement between manufacturer and user, but shall be at least as severe as those for **IP_7**.

Abridged Descriptions of NEMA Enclosure Test Requirements

NEMA is a commonly recognized standards organization in North America and publishes standards for enclosures. It does not require independent verification of these tests.

6.2 Rod Entry Test

A 3.18 mm (0.125 in.) diameter rod must not be able to enter enclosure except at locations where nearest live part is more than 102 mm (4 in.) from an opening — such opening shall not permit a 13 mm (0.5 in.) diameter rod to enter.

6.3 Drip Test

Water is dripped onto enclosure for 30 minutes from an overhead pan having uniformly spaced spouts, one every 12,900 mm^2 (20 $in.^2$) of pan area, each spout having a drip rate of 20 drops per minute.

Evaluation 6.3.2.2: No water shall have entered enclosure.

6.4 Rain Test

Entire top and all exposed sides are sprayed with water at a pressure of
0.35 kg/cm2 (5 psi) from nozzles for one hour at a rate to cause water to rise 457 mm (18 in.) in a straight-sided pan beneath the enclosure.

Evaluation 6.4.2.1: No water shall have reached live parts, insulation, or mechanisms.

Evaluation 6.4.2.2: No water shall have entered enclosure.

6.5.1.1 (2) Outdoor Dust Test (Alternate Method)

Enclosure and external mechanisms are subjected to a stream of water at 170.5 liters (45 gallons) per minute from a 25.4 mm (1 in.) diameter nozzle, directed at all joints from all angles from a distance of 3...3.7 m (10...12 ft). Test time is 48 seconds times the test length (height + width + depth of enclosure in feet), or a minimum of 5 minutes. No water shall enter enclosure.

6.5.1.2 (2) Indoor Dust Test (Alternate Method)

Atomized water at a pressure of 2.11 kg/cm2 (30 psi) is sprayed on all seams, joints and external operating mechanisms from a distance of 305...381 mm (12...15 in.) at a rate of 11 liters (3 gallons) per hour. No less than 142 gms
(5 oz) of water per linear foot of test length (height + length + depth of enclosure) is applied. No water shall enter enclosure.

6.6 External Icing Test

Water is sprayed on enclosure for one hour in a cold room 2 °C (36 °F); then room temperature is lowered to approximately –5 °C (–23 °F) and water spray is controlled so as to cause ice to build up at a rate of 6.4 mm (0.25 in.) per hour until 19 mm (0.75 in.) thick ice has formed on top surface of a 25.4 mm (1 in.) diameter metal test bar, then temperature is maintained at –5 °C (–23 °F) for 3 hours.

Evaluation 6.6.2.2: Equipment shall be undamaged after ice has melted (external mechanisms not required to be operable while iceladen).

6.7 Hosedown Test

Enclosure and external mechanisms are subjected to a stream of water at 246 liters (65 gallons) per minute from a 25.4 mm (1 in.) diameter nozzle, directed at all joints from all angles from a distance of 3...3.7 m (10...12 ft). Test time is 48 seconds times the test length [height + width + depth] of enclosure in meters (feet), or a minimum of 5 seconds. No water shall enter enclosure.

6.8 Rust Resistance Test (Applicable Only to Enclosures Incorporating External Ferrous Parts)

Enclosure is subjected to a salt spray (fog) for 24 hours, using water with five parts by weight of salt (NaCl), at 35 °C (95 °F), then rinsed and dried. There shall be no rust except where protection is impractical (for example, machined mating surfaces, sliding surfaces of hinges, shafts, etc.).

6.9 Corrosion Protection

Sheet steel enclosures are evaluated per Underwriter's Laboratories (UL) 50, Part 13 (test for equivalent protection as G-90 commercial zinc coated sheet steel). Other materials per Underwriter's Laboratories (UL) 508, 6.9 or 6.10.

6.11 (2) Air Pressure Test (Alternate Method)

Enclosure is submerged in water at a pressure equal to water depth of 2 m (6 ft), for 24 hours. No water shall enter enclosure.

6.12 Oil Exclusion Test

Enclosure is subjected to a stream of test liquid for 30 minutes from a 9.5 mm (0.375 in.) diameter nozzle at 7.57 liters (2 gallons) a minute. Water with 0.1% wetting agent is directed from all angles from a distance of 305...457 mm (12...18 in.), while any externally operated device is operated at 30 operations per minute. No test liquid shall enter the enclosure.

Abridged Descriptions of UL Standard 698 Test Requirements

The following descriptions are based on the descriptions in the UL Standard 698 Test Requirements.

Explosion Test

During a series of tests in which gas-air mixtures of the specific gas, over its range of explosive concentrations, are ignited inside the enclosure, the enclosure shall prevent the passage of flame and sparks capable of igniting a similar gas-air mixture surrounding the enclosure. In addition, there shall be no mechanical damage to enclosed electrical mechanisms or the enclosure.

Hydrostatic Test

The enclosure shall withstand for one minute a hydrostatic test based on the maximum internal explosion pressure developed during the explosion tests, as follows: cast metal, four times the explosion pressure without rupture or permanent deformation; fabricated steel, twice the explosion pressure without permanent deformation and three times the explosion pressure without rupture. Exception: Hydrostatic tests can be omitted if calculations show safety factor of 5:1 for cast metal, and 4:1 for fabricated steel.

Temperature Test

The enclosed device is subjected to a temperature test to determine maximum temperature at any point on the external surface. The device must be marked with a temperature code based on the result only if the temperature exceeds 100 °C (212 °F).

Dust Penetration Test

The device is operated at full rated load until equilibrium temperatures are attained, then allowed to cool to ambient (room) temperature, through six heating and cooling cycles covering at least 30 hours, while continuously exposed to circulating dust of specified properties in a test chamber. No dust shall enter the enclosure.

Temperature Test with Dust Blanket

This test is conducted as described for the Dust Penetration test except that the re-circulating dust nozzles are positioned so that the dust is not blown directly on the device under test. The device is operated at full rated load (and under abnormal conditions for equipment subject to overloading) until equilibrium temperatures are attained. Dust in contact with the enclosure shall not ignite or discolor from heat, and the exterior surface temperatures based on 40 °C (104 °F) ambient shall not exceed the values listed below.

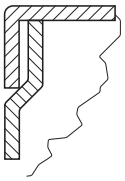
Class II, Group	Normal Operating Conditions	Abnormal Operating Conditions
E	200 °C (392 °F)	200 °C (392 °F)
F	150 °C (302 °F)	200 °C (392 °F)
G	120 °C (248 °F)	165 °C (329 °F)

Enclosure Type Descriptions

This section provides enclosure type descriptions for hazardous and non-hazardous locations.

Type 1 – General Purpose Surface Mounting

Type 1 enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment in locations where unusual service conditions do not exist. The enclosures are designed to meet the rod-entry and rust-resistance design tests. Enclosure is sheet steel, treated to resist corrosion.



Type 1 – Flush Mounting

Type 1 Flush Mounting enclosures for installation in machine frames and plaster wall. These enclosures are for similar applications and are designed to meet the same tests as Type 1 surface mounting.

Type 3 – Rainproof Dusttight

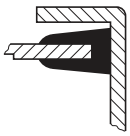
Type 3 enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet; and to be undamaged by the formation of ice on the enclosure. They are designed to meet rain(1), external icing(2), dust, and rust-resistance design tests. They are not intended to provide protection against conditions such as internal condensation or internal icing.

Type 3R – Rainproof

Type 3R enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain, and to be undamaged by the formation of ice on the enclosure. They are designed to meet rod entry, rain(3) external icing(4), and rust resistance design tests. They are not intended to provide protection against conditions such as dust, internal condensation, or internal icing.

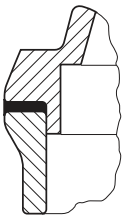
Type 4 – Watertight

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; and to be undamaged by the formation of ice on the enclosure. They are designed to meet hosedown, dust, and external icing tests(4). They are not intended to provide protection against conditions such as internal condensation or internal icing.



Type 4X – Non-metallic, Corrosion-resistant

Type 4X enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, and hose-directed water; and to be undamaged by the formation of ice on the enclosure. They are designed to meet the hosedown, dust, external icing(4), and corrosion-resistance design tests. They are not intended to provide protection against conditions such as internal condensation or internal icing.

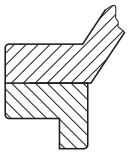


(1) Evaluation criteria: No water has entered enclosure during specified test.
(2) Evaluation criteria: Undamaged after ice buildup during specified test has melted. (**Note:** Not required to be operable while iceladen.)
(3) Evaluation criteria: No water shall have reached live parts, insulation or mechanisms.
(4) Evaluation criteria: Undamaged after ice buildup during specified test has melted. (**Note:** Not required to be operable while iceladen.)

Type 6P – For Prolonged Submersion at a Limited Depth

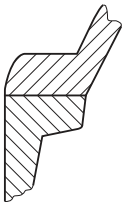
Type 6P enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against the entry of water during prolonged submersion at a limited depth; and to be undamaged by the formation of ice on the enclosure. They are designed to meet air pressure, external icing[(1)], hosedown and corrosion-resistance design tests. They are not intended to provide protection against conditions such as internal condensation or internal icing.

Type 7 – For Hazardous Gas Locations



Type 7 enclosures are for indoor use in locations classified as Class I, Groups C or D, as defined in the U.S. National Electrical Code. Type 7 enclosures are designed to be capable of withstanding the pressures resulting from an internal explosion of specified gases, and contain such an explosion sufficiently that an explosive gas-air mixture existing in the atmosphere surrounding the enclosure will not be ignited. Enclosed heat generating devices are designed not to cause external surfaces to reach temperatures capable of igniting explosive gas-air mixtures in the surrounding atmosphere. Enclosures are designed to meet explosion, hydrostatic, and temperature design tests. Finish is a special corrosion-resistant, gray enamel.

Type 9 – For Hazardous Dust Locations

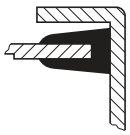


Type 9 enclosures are intended for indoor use in locations classified as Class II, Groups E, F, or G, as defined in the U.S. National Electrical Code. Type 9 enclosures are designed to be capable of preventing the entrance of dust. Enclosed heat generating devices are designed not to cause external surfaces to reach temperatures capable of igniting or discoloring dust on the enclosure or igniting dust-air mixtures in the surrounding atmosphere. Enclosures are designed to meet dust penetration and temperature design tests, and aging of gaskets. The outside finish is a special corrosion-resistant gray enamel.

Type 12 – Dusttight Industrial Use

Type 12 enclosures are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dripping non-corrosive liquids. They are designed to meet drip [(2)], dust, and rust-resistance tests. They are not intended to provide protection against conditions such as internal condensation.

Type 13 – Oiltight



Type 13 enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and noncorrosive coolant. They are designed to meet oil exclusion and rust-resistance design tests. They are not intended to provide protection against conditions such as internal condensation.

(1) Evaluation criteria: No water has entered enclosure during specified test.
(2) Evaluation criteria: Undamaged after ice buildup during specified test has melted. (**Note:** Not required to be operable while iceladen.)

Enclosure Type Descriptions for Non-hazardous Locations

This section compares the enclosure type descriptions for non-hazardous locations between NEMA, UL, and CSA standards.

Location	Enclosure Type	NEMA(1)	UL(2) (3)	CSA(4)
Indoor	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 dirt.	General purpose enclosure. Protects against accidental contact with live parts.
Indoor	Type 12	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, falling dirt and dripping noncorrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water and external condensation of noncorrosive 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.
Indoor	Type 12K	Enclosures with knockouts are intended for indoor use primarily to provide a degree of protection against dust, falling dirt and dripping noncorrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water and external condensation of noncorrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of noncorrosive liquids; not provided with knockouts.
Indoor	Type 13	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil and noncorrosive coolant.	Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil and noncorrosive 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.
Outdoor	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 windblown dust; undamaged by the external formation of ice on the enclosure.
Outdoor	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.
Outdoor	Type 3RX	Enclosures are intended for outdoor use primarily to provide a degree of protection against corrosion, falling rain and sleet; undamaged by the formation of ice on the enclosure.	Not specifically defined.	Not specifically defined.
Outdoor	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.
Outdoor	Type 4X	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, 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; 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.
Outdoor	Type 6P	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.

(1) Reprinted from NEMA 250-2008, Enclosure Type Non-Hazardous Location, Enclosure Type descriptions, by permission of the National Electrical Manufacturers Association.
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Enclosures Offered by Rockwell Automation

See Selection Criteria for Non-hazardous Locations and Selection Criteria for Hazardous Locations (division 1 or 2) for the types of enclosures offered by Rockwell Automation. For definitions, descriptions, and test criteria, see National Electrical Manufactures Association (NEMA) Standards Publication No. 250. Also see individual product listings within the Safety Products page, (https://ab.rockwellautomation.com/Safety), for available enclosure types and for any additional information relating to these descriptions.

Note: Enclosures do not normally protect devices against conditions such as condensation, icing, corrosion, or contamination that can occur within the enclosure or enter via the conduit or unsealed openings. You must make adequate provisions to safeguard against such conditions and be sure that the equipment is properly protected.

Selection Criteria for Non-hazardous Locations

For a Degree of Protection Against:	Designed to Meet Test No.(1)	Type							
		For Indoor Use			For Outdoor Use		Indoor or Outdoor		
		1	12	13	3R	3	4	4X	6P
Incidental contact with enclosed equipment	6.2	x	x	x	x	x	x	x	x
Falling dirt	6.2	x	x	x	x	x	x	x	x
Rust	6.8	x	x	x	x	x	x	x	x
Circulating dust, lint, fibres, and flyings(2)	6.5.1.2 (2)		x	x		x	x	x	x
Windblown dust	6.5.1.1 (2)					x	x	x	x
Falling liquids and light splashing	6.3.2.2		x	x		x	x	x	x
Rain (Test evaluated per 6.4.2.1)	6.4.2.1				x	x	x	x	x
Rain (Test evaluated per 6.4.2.2)	6.4.2.2					x	x	x	x
Snow and sleet	6.6.2.2				x	x	x	x	x
Hosedown and splashing water	6.7						x	x	x
Occasional prolonged submersion	6.11 (2)								x
Oil and coolant seepage	6.3.2.2		x	x					
Oil or coolant spraying and splashing	6.12			x					
Corrosive agents	6.9				x	x	x	x	x

(1) Non-hazardous materials, not Class III ignitable or combustible.
(2) See Enclosure Type Descriptions for Non-hazardous Locations on page 19. Refer to NEMA Standards Publication No. 250 for complete test specifications.

Selection Criteria for Hazardous Locations (division 1 or 2)

For a Degree of Protection Against Atmospheres Typically Containing: (1) (2)	Designed to Meet Tests(3)	Class (National Electrical Code)	7, Class I Group				9, Class II Group		
			A	B	C	D	E	F	G
Acetylene	Explosion Test Hydrostatic Test Temperature Test	I	X						
Hydrogen, Manufactured Gas			X	X					
Diethyl Ether, Ethylene, Hydrogen Sulfide					X				
Acetone, Butane, Gasoline, Propane, Toluene					X	X			
Metal dusts and other combustible dusts with resistivity of less than 10^5 Ω-cm	Dust Penetration Test Temperature Test with Dust Blanket	II					X		
Carbon black, charcoal, coal or coke dusts with resistivity between $10^2 \ldots 10^8$ Ω-cm								X	
Combustible dusts with resistivity of 105 Ω-cm or greater									X
Fibers, flyings	(4)	III							X

(1) For indoor locations only, unless cataloged with additional NEMA Type enclosure number(s) suitable for outdoor use as shown in the table on this page. Some control devices (if so listed in the catalog) are suitable for Division 2 hazardous location use in enclosures for nonhazardous locations. For explanation of CLASSES, DIVISIONS and GROUPS, refer to the National Electrical Code.
(2) For listing of additional materials and information noting the properties of liquids, gases and solids, refer to NFPA 497M-1991, Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations.
(3) See Enclosure Type Descriptions for Non-hazardous Locations on page 19. For complete requirements, refer to UL Standard 698, compliance with which is required by NEMA enclosure standards.
(4) UL 698 does not include test requirements for Class III. Products that meet Class II, Group G requirements are acceptable for Class III.

Industry Related Installation Considerations

This section describes different installation considerations for specific industries. It is not meant to be a comprehensive list and you must take into account conditions at your specific location.

General Precautions

ATTENTION: Only qualified personnel familiar with adjustable frequency AC drives and associated machinery should plan or implement the installation, start-up and subsequent maintenance of the system. Failure to comply can result in personal injury and/or equipment damage.

ATTENTION: An incorrectly applied or installed drive can result in component damage or a reduction in product life. Wiring or application errors such as under sizing the motor, incorrect or inadequate AC supply, or excessive surrounding air temperatures can result in malfunction of the system.

ATTENTION: Severe injury or death can result from electrical shock, burn, or unintended actuation of controlled equipment. Hazardous voltages can exist in the drive enclosure even with the circuit breaker in the off position. Recommended practice is to disconnect and lock out control equipment from power sources. If it is necessary to work in the vicinity of energized equipment, the safety related work practices of NFPA 70E, Electrical Safety Requirements for Employee Workplaces, must be followed. DO NOT work alone on energized equipment.

ATTENTION: To avoid an electric shock hazard, verify that the voltage on the bus capacitors has discharged before performing any work on the drive. Measure the DC bus voltage at the +DC and -DC terminals of the Power Terminal Block. The voltage must be zero.

General Information

As with any AC drive installation there are many items that must be considered. In general, the selection of an enclosure for an AC drive is based on the type of environment in which the AC drive will be applied. Specific industries have known contaminants which can contain particulate matter (solids) and/or harsh chemical gases, and potentially higher ambient temperatures that can require filtering, additional air flow, or complete sealing of an enclosure to protect the AC drive from the contaminant source.

Contaminants and Conditions by Industry

There are known contaminants in the atmosphere based on the type of application, location of the facility, or location (placement) of the AC drive (for example: indoor vs. outdoor). This section lists some typical contaminants present in various industries.

Also see Environmental and Atmospheric Considerations by Location on page 23) and Table 5 on page 29.

Automotive Industry

In the Automotive industry the AC drive is typically an indoor installation. The airborne contaminants that can be present are:

- Hydrogen fluoride
- Oxides of nitrogen
- Hydrocarbons
- Sulfur dioxide

Chemical/Specialty Chemical

In the Chemical/Specialty Chemical industries, the AC drive can be found in both indoor and outdoor installations. The airborne contaminants that can be present are:

- Organic dust (elemental chemicals such as sulfur)
- Oil-based distillates, which can create an oily film, further attracting other contaminants.
- High humidity levels in outdoor installations
- Caustic cleaners and / or concentrates (for example, ammonia, sodium chloride)
- High-pressure wash down
- NEMA4/4X environment
- Alcohol (Class1, Div 1, environment)
- Hose-directed water which can contain cleaning and other chemicals

Food and Beverage

In the Food and Beverage industry the AC drive is typically an indoor installation. The airborne contaminants that can be present are:

- Organic dust (grains, sugars, etc.)
- Caustic cleaners and/or concentrates (ammonia, sodium chloride, syrups)
- High-pressure wash down
- NEMA4/4X environment
- Alcohol (Class 1, Div 1, environment)
- High temperature/industrial cooking and baking 35 °C (95 °F)

Forest Products Industry/Converting

In the Forest Products/Converting industries, the AC drive is typically an indoor installation. The airborne contaminants that can be present are:

- Hydrogen sulfide
- Active organic nitrogen
- Carbon monoxide
- Chlorine
- Chlorine dioxide
- Hydrocarbons
- Phosphates
- High moisture or humidity

Mining and Steel

In the Mining and Steel industry the AC drive is typically an indoor installation. The airborne contaminants that can be present are:

- Hydrogen sulfide,
- Hydrogen fluoride,

- Carbon,
- Carbon monoxide,
- Inorganic dust,
- Pickle line acid,
- Hydrochloric acid,
- Moisture or humidity

Tire Manufacturing

In the Tire Manufacturing industry the AC drive is typically an indoor installation. The airborne contaminants that can be present are:

- Hydrogen sulfide
- Mercaptans
- Carbon black

Water/Waste Water

In the Water/Waste Water industry the AC drive can be installed either indoors or outdoors. With an indoor installation the airborne contaminants that can be present are:

- Hydrogen sulfide
- Active organic nitrogen
- Carbon monoxide
- Chlorine
- Chlorine dioxide
- Hydrocarbons
- Moisture or humidity

Marine and Offshore

In the Marine and Offshore industry the AC drive can be installed either indoor (controlled), indoor (uncontrolled or ventilated), or outdoor (above deck). With an outdoor and indoor (uncontrolled) installation, the environmental conditions that can be present are:

- Salt air
- Fuel oil
- Cleaning solvents
- Corrosive or acidic rain
- High-pressure wash down from hose-directed water or sea water
- Biological elements when in direct contact with sea water

Environmental and Atmospheric Considerations by Location

Location of the AC Drive	Environmental and Atmospheric Considerations
Indoor (Environmentally Controlled)	Clean air control room, temperature regulated, moisture content, size of the smallest airborne contaminant, corrosive or combustible gasses, wash-down areas.
Indoor (Uncontrolled Environment)	Non-conditioned plant floor areas, shipboard machinery rooms, or other fan-ventilated areas. Not typical temperature regulated, uncontrolled moisture content, airborne contaminant limited by ventilation system and filters, wash-down areas.
Outdoor	Maximum and minimum ambient temperatures, wind, rain, snow, dust, direct sunlight (solar heating), close proximity to the ocean or salt air, seismic activity.

The International Society of Automation (ISA) standard Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants (ISA-71.04-2013) describes many of the types of contamination and categorizes the severity of environments. The ISA defines four severity levels as described in Explanation of Contaminant Severity Levels, below.

Explanation of Contaminant Severity Levels

This section describes contaminant severity levels to standardize descriptions across different industries.

Explanation of Contaminant Severity Levels

There is a broad distribution of contaminant concentrations and reactivity levels existing within industries using process measurement and control equipment. Some environments are severely corrosive, while others are mild.

The purpose of the contaminant classes is to define environments on the basis of corrosion rate of specially prepared and tested copper and silver samples, which is prepared and tested as described in Appendix C of ISA-71.04-2013.

Severity Level G1

Mild – An environment sufficiently well-controlled such that corrosion is not a factor in determining equipment reliability.

Severity Level G2

Moderate – An environment in which the effects of corrosion are measurable and can be a factor in determining equipment reliability.

Severity Level G3

Harsh – An environment in which there is a high probability that corrosive attack will occur. These harsh levels should prompt further evaluation resulting in environmental controls or specially designed and packaged equipment.

Severity Level GX

Severe – An environment in which only specially designed and packaged equipment would be expected to survive. Specifications for equipment in this class are a matter of negotiation between user and supplier.

Table 2 - Classification of Reactive Environments (ISA Table 3)

Severity Level	G1 Mild	G2 Moderate	G3 Harsh	Gx Severe
Copper reactivity level (in angstroms)(1)	<300	<1000	<2000	≥2000
Silver reactivity level (in angstroms)(1)	<200	<1000	<2000	≥2000

(1) Normalized to a 30-day exposure. See Annex C, item numbers C.2, C.3 of ISA-71.04-2013.

Both copper and silver reactivity levels shall be used for environmental monitoring with the higher of the copper and silver corrosion rates determining the overall severity level.

For reliable operation of electronic equipment, a G1 level should be maintained around the electronics. The following chart from the ISA standard further describes the severity levels.

The gas concentration levels shown in Table 3 are provided for reference purposes. They are believed to approximate the Copper Reactivity Levels stated in Table 2, providing the relative humidity is less than 50%. For a given gas concentration, the Severity Level (and Copper

Reactivity Level) can be expected to be increased by one level for each 10% increase in relative humidity above 50% or for a humidity rate of change greater than 6% per hour.

Table 3 - Contaminant Concentrations Versus Severity Levels (ISA Table B1)

Severity Level			G1 Mild	G2 Moderate	G3 Harsh	GX Severe
Contaminant		Gas	Gas Concentration (1)			
Reactive Species (1)(2)	Group A	H_2S	<3	<10	<50	≥50
		SO_2, SO_3	<10	<100	<300	≥300
		Cl_2	<1	<2	<10	≥10
		NO_x	<50	<125	<1250	≥1250
	Group **B** (3)	HF	<1	<2	<10	≥10
		NH_3	<500	<10,000	<25,000	≥25,000
		O_3	<2	<25	<100	≥100

(1) Parts per billion by volume (ppbv) average for test period for the gases in Groups A and B.
(2) The Group A contaminants often occur together and the reactivity levels include the synergistic effects of these contaminants.
(3) The synergistic effects of Group B contaminants are not known at this time.

Relative Humidity

High relative humidity accelerates the corrosion caused by gaseous contaminants in an exponential manner. Equally important is recognition of the fact that temperature fluctuations dramatically affect relative humidity and often induce local condensation. Although water is universally present in industrial atmospheres, the concentration varies widely. It promotes the corrosive degradation of equipment in three major ways:

1. Directly, as a reactive chemical attacking metals and plastics.
2. Interactively with other atmospheric constituents, in most cases forming a more reactive combination; an example is sulfur dioxide, SO_2, which combines with water to form sulfurous acid.
3. Electrochemically: Many species when dissolved in water form a conductive solution. When electric potential differences exist between two dissimilar metals, the conditions for electrolytic or galvanic corrosion processes are set up. These are different phenomena, but both are caused by and/or promoted by an electrolyte.

Duty Rating of the AC Drive Application

When designing AC drive enclosure systems for any environment, a consideration of the operating duty rating is useful in determining the worst-case temperature rise. The internal AC drive enclosure consists of components with continuous heat losses and those which are generated while power components are conducting. When considering the later, an understanding of the duty rating of the system is useful in determining the required enclosure cooling system. Always consider the published maximum operating temperature to be the highest permissible temperature for the air inside an enclosure containing the drive (unless you first consult with the factory). Below are some definitions of the different types of duty ratings from least to most stringent.

Periodic Duty Rating

The periodic duty rating of a rotating machine is the rated kW load at which the machine can operate repeatedly, for specified period (N) at the rated load followed by a specified period (R) of rest and de-energized state, without exceeding the given maximum temperature.

Short-time Duty Rating

The short-time duty rating of a rotating electrical machine is the rated kW load at which the machine can operate for a specified time period without exceeding the given temperature. A rest and de-energized period sufficient to re-establish the machine temperature prior to the next operation is allowed.

Non-periodic Duty Rating

The non-periodic duty rating of a rotating electrical machine is the kW load at which the machine can operate continuously, for a specific period of time, or intermittently under the designed variations of the load and speed within the permissible operating range, respectively; and the given temperature, measured when the machine has been run until it reaches a steady temperature condition.

Continuous Duty Rating

The continuous duty rating of a rotating electrical machine is the rated kW load at which the machine can continuously operate without exceeding the given steady state temperature.

Protecting Electronic Modules From Contaminants

This section describes different methods of protecting electronic components from contaminants.

Shielding by Enclosures

The most effective control for reducing the rate of corrosion is shielding the electronic modules by appropriate enclosures. If the environment is not too severe then simple enclosures, such as NEMA Type 12, can be adequate. To provide protection from the process environment, the enclosure must have a low air-exchange rate. To achieve this there must be no openings of the enclosure walls, and doors must be maintained closed. A well-sealed enclosure will protect against fibers, dust, splashing, and dripping.

If temperature rise within the enclosure is a concern, heat exchangers or air conditioners can be used. To prevent condensation from occurring, be sure that air conditioners do not blow cold air directly to the electronic modules. Some temperature rise within the enclosure actually reduces the rate of corrosion by depressing the relative humidity. This reduction in humidity can be significant even with modest temperature rises.

If the environment has high humidity, or cyclic high humidity, the electronic equipment can be powered on at all times to keep the inside of the enclosure dry. If this is not practical, install anti-condensation heaters for when the equipment is not powered on or not running. In addition to the correct enclosure solution, the printed circuit boards of the AC drive should be conformally coated for added protection against corrosion to internal sensitive circuits.

Source Control

In some applications the contaminants have a localized source. Isolate the contamination from the electronic equipment using ventilation, segregation of environments, equipment closets, control rooms, or other barriers and methods.

Ventilation Control and Removal Control

If the environment is severe, more aggressive control can be necessary. Ventilation of the control room with a clean source of air can be required. Typically, a slight positive pressure prevents the room from filling with contaminants. For ventilation alone to be successful, a clean source of air must be available. Also in severe environments, active removal control can be required. This can involve control rooms with active air filtration systems. A variety of filter media is available including activated carbon and permanganate impregnated alumina. Environmental control companies can help design the optimum system to prevent contamination and corrosion.

Outdoor Installations

For outdoor installations, follow the same shielding and control precautions listed above to protect against contaminants; however, the outdoor environment is now a factor as well. The AC drive carries a specified ambient temperature rating for proper operation which must be maintained in the outdoor environment. Generally, outdoor installations require a sealed enclosure system with additional cooling. If the equipment is placed in direct sunlight, you must also consider the effects of additional solar heating. If the equipment is placed in cold or damp locations, you must also consider internal heaters to maintain at minimum the lowest specified temperatures during periods when the equipment is not running.

Protecting Electronic Modules During Installation

Because of direct exposure to the process environment during installation, the electronic modules can be exposed to contaminants and are susceptible to corrosion damage. After this exposure, failures can occur even after the electronic modules are sealed within enclosures. To minimize the potential for failure, follow these precautions.

- Complete the construction and wiring (as much as possible) of the control rooms before the electronic modules are unpacked.
- Minimize the time the electronic modules remain in an unprotected area.
- Always use protective bags for electronic module storage.
- Keep doors to control rooms and enclosures closed unless opening the door is a necessity.

IMPORTANT Rockwell Automation strongly recommends the use of grounded neutral systems. See Delta/Wye with Grounded Wye Neutral on page 31.

Sources of Reactive Contaminants and Emissions

Additional information on common sources of reactive contaminants and emissions from natural and industrial process can be found in Table 4 and Table 5. These include corrosive contaminants that can be liquid, solid, or gaseous in nature.

Table 4 - Common Sources of Reactive Environmental Constituents (ISA Table B2)

Category	Symbol	Constituent	Some Common Sources
Gas	H_2S	Hydrogen Sulfide	Geothermal emissions, microbiological activities, fossil fuel processing, wood pulping, sewage treatment, combustion of fossil fuel, auto emissions, ore smelting, sulfuric acid manufacture
Gas	SO_2, SO_3	Sulfur dioxide	Combustion of fossil fuel, auto emissions, ore smelting, sulfuric acid manufacture, tobacco smoke
Gas	S_8, R-SH	Mercaptans	Foundries, sulfur manufacture
Gas	HF	Hydrogen fluoride	Fertilizer manufacture, aluminum manufacture, ceramics manufacture, steel manufacture, electronics device manufacture, fossil fuel
Gas	NOx	Oxides of nitrogen	Automobile emissions, fossil fuel combustion, microbes, chemical industry
Gas	N_2	Active organic nitrogen	Automobile emissions, animal waste, vegetable combustion, sewage, wood pulping
Gas	NH_3	Ammonia	Microbes, sewage, fertilizer manufacture, geothermal steam, refrigeration equipment, cleaning products, reproduction (blueprint) machines
Solid	C	Carbon	Incomplete combustion (aerosol constituent), foundry

Table 4 - Common Sources of Reactive Environmental Constituents (ISA Table B2) (Continued)

Category	Symbol	Constituent	Some Common Sources
Gas	CO	Carbon monoxide	Combustion, automobile emissions, microbes, trees, wood pulping
Gas	Cl_2, ClO_2	Chlorine, chlorine dioxide	Chlorine manufacture, aluminum manufacture, paper mills, refuse decomposition, cleaning products
Gas	HCl	Hydrogen chloride	Automobile emissions, combustion, oceanic processes, polymer combustion
Gas	HBr, HI	Halogen compounds	Automotive emissions
Liquid	Cl	Chloride ions	Aerosol content, oceanic processes, ore processing
Gas	O_3	Ozone	Atmospheric photochemical processes mainly involving nitrogen oxides and oxygenated hydrocarbons, automotive emissions, electrostatic filters
Gas	C_nH_n	Hydrocarbons	Automotive emissions, fossil fuel processing, tobacco smoke, water treatment, microbes, paper mill, and many other sources, both natural and industrial
Solid	—	Inorganic dust	Crystal rock, rock and ore processing, combustion, blowing sand, and many industrial sources

Table 5 - Common Emissions of Natural and Industrial Processes (ISA Table B3)

Natural Processes	Emissions
Microbes	H_2, NH_3, NOx, H_2S, CO, large variety of organics of many types
Sewage	NH_3, aldehydes, many organics, H_2S, mercaptans, H_2, S, CO
Geothermal	H_2, H_2S, SO_2
Marshy area	H_2S, NH_3, SO_2
Animal matter	Many organics, mainly oxygenated
Forest fire	HCl, CO, CO_2
Oceans	NaCl, chloride ions
Industrial Processes	**Emissions**
Power generation	SO_2, C, CO, NOx, hydrocarbons, organics
Automotive combustion	SO_2, SO_3, HCl, HBr, NOx, hydrocarbons, organics, CO, HBr
Diesel combustion	CO, NOx, many organics
Fossil fuel processing	H_2S, S, SO_2, NH_3, hydrocarbons, other organics, mercaptans
Plastic manufacture	All organics, aldehydes, alcohols, NH_3, SO_2
Cement plants	SO_3, dust, SO_2, NOx, CO
Steel blast furnaces	H_2S, SO_2, CO, HF, coal dust
Steel electric furnaces	H_2S, SO_2, C, CO
Coke plants	H_2S, CO, HCN, carbon, dust
Pulp manufacture	Cl_2, SO_2, H_2S, CO, wood fibers, dust
Chlorine plants	Chlorine, chlorine compounds, NaCl
Fertilizer manufacture	HF, NH_3, CH_4, gas, liquids, dust, acids
Food processing	Hydrocarbons, many organics
Rubber manufacture	H_2S, S_8, R-SH
Paint manufacture	C, hydrocarbons, oxygenated hydrocarbons, dust
Aluminum manufacture	HF, SO_2, C, dust
Ore smelting	SO_2, CO, H_2, dust
Tobacco smoke	H_2S, SO_2, HCN, CO, tars and particulates
Gasoline and fuel vapors	Hydrocarbons, oxygenated hydrocarbons
Battery manufacture	SO_2, acids, dust

Notes:

System Configurations, Grounding, Application, and Control

For system configurations, grounding, application, and control, you must consider the specific application of the AC drive, for example: Pumping, Fan Operation, Conveyor, etc., and the electrical characteristics surrounding that specific application and the different types of power distribution to which the applications are applied.

Power Distribution

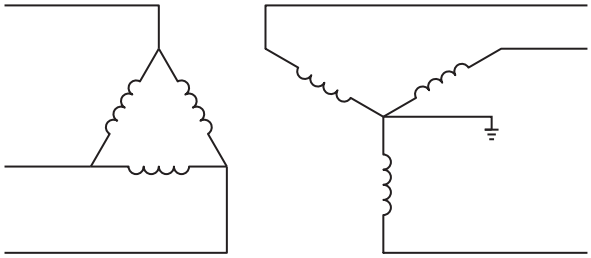
You must evaluate and configure the power distribution systems to provide optimum performance for the AC drive. See System Configurations and Grounding, below.

For more information, see the Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001.

System Configurations and Grounding

The type of transformer and the connection configuration feeding a drive plays an important role in the performance and safety of the drive. The following is a brief description of some of the more common configurations and a discussion of their qualities and differences.

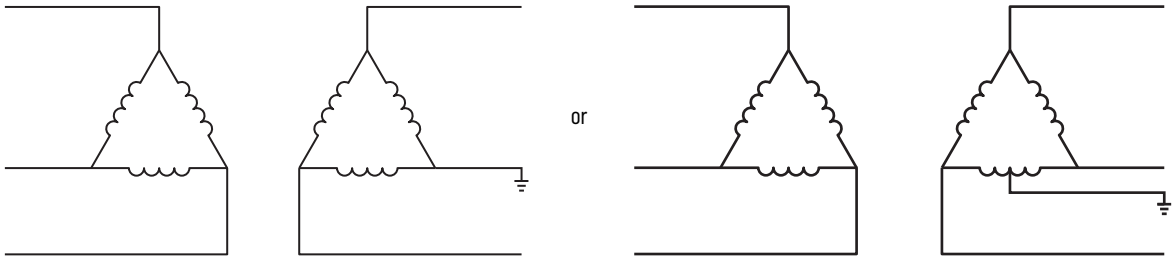
Delta/Wye with Grounded Wye Neutral



Delta/Wye with Grounded Wye Neutral is the most common type of distribution system. It provides a 30-degree phase shift. The grounded neutral provides a direct path for common mode current caused by the drive output (see Chapter 3 and Chapter 6 of Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001).

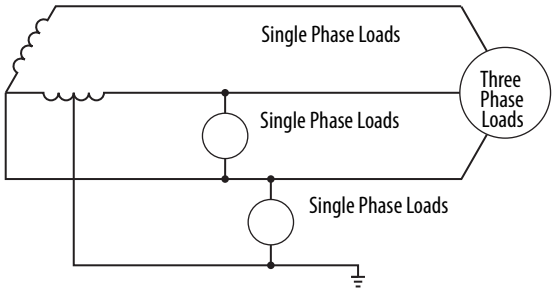
IMPORTANT	Rockwell Automation strongly recommends the use of grounded neutral systems for the following reasons: • Controlled path for common mode noise current • Consistent line to ground voltage reference, which minimizes insulation stress • Accommodation for system surge protection schemes

Delta/Delta with Grounded Leg or Four-wire Connected Secondary Delta



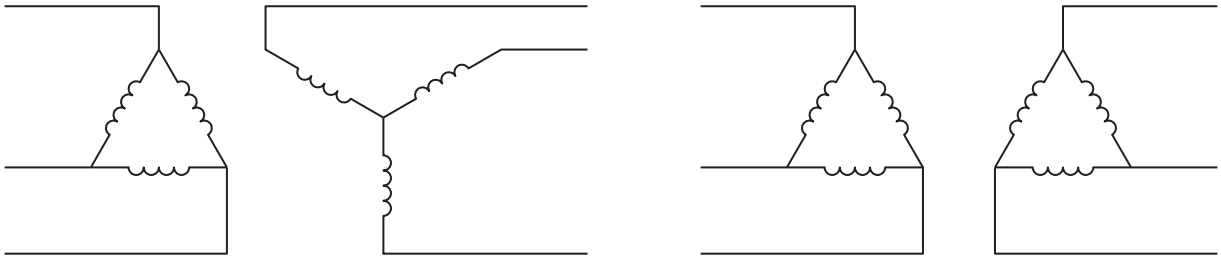
Delta/Delta with Grounded Leg or Four-wire Connected Secondary Delta is a common configuration with no phase shift between input and output. The grounded center tap provides a direct path for common mode current caused by the drive output.

Three-phase Open Delta with Single-phase Center Tapped



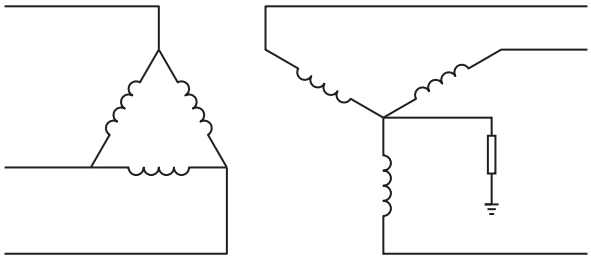
Three-phase Open Delta with Single-phase Center Tapped is a configuration providing a three-phase delta transformer with one side tapped. This tap (the neutral) is connected to earth. The configuration is called the antiphase grounded (neutral) system. The open delta transformer connection is limited to 58% of the 240V, single-phase transformer rating. Closing the delta with a third single-phase, 240V transformer allows full rating for the two single-phase, 240V transformers. The phase leg opposite the midpoint has an elevated voltage when compared to earth or neutral. The "hottest" high leg must be positively identified throughout the electrical system. It should be the center leg in any switch, motor control, three-phase panel board, etc. The NEC requires orange color tape to identify this leg.

Ungrounded Secondary



Grounding the transformer secondary is essential to the safety of personnel and safe operation of the drive. Leaving the secondary floating allows dangerously high voltages between the chassis of the drive and the internal power structure components. Exceeding the voltage rating of the drive's input MOV (Metal Oxide Varistor) protection devices could cause the drive to fail. In all cases, the input power to the drive should be referenced to ground. If the system is ungrounded, other general precautions such as a system level ground fault detector or system level line to ground suppressor can be necessary or an isolation transformer must be considered with the secondary of the transformer grounded. Refer to local codes regarding safety requirements. Also refer to the Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, Surge Protection MOVs and Common Mode Capacitors.

High Resistance Ground



Grounding the wye secondary neutral through a resistor is an acceptable method of grounding. Under a short circuit secondary condition, any of the output phases to ground will not exceed the normal line to line voltage. This is within the rating of the MOV input protection devices on the drive. The resistor is often used to detect ground current by monitoring the associated voltage drop. Since high frequency ground current can flow through this resistor, be sure to properly connect the drive motor leads using the recommended cables and methods. In some cases, multiple drives (that can have one or more internal references to ground) on one transformer can produce a cumulative ground current that can trigger the ground fault interrupt circuit. Refer to the Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, Surge Protection MOVs and Common Mode Capacitors.

Application and Control

This section describes typical application and control strategies for different industries.

Automotive Industry

The Automotive industry uses low voltage (LV) AC drives in many different applications which can include the control of fans, pumps, press, conveyor, and lifting applications, to name a few. It is very important to understand which process the drive will be applied to as the environment and type of drive will vary in every application.

Review the motor cable distances. The use of an appropriate output device can be required based on cable distance, motor insulation, and desired operating carrier frequency (PWM Frequency). See Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, for details on motor cable length restrictions.

Chemical and Specialty Chemical Industry

Typically, AC drives in the Chemical/Specialty Chemical industry include the control of pumps and fans. These applications are normally variable torque (normal duty) rated and only require 115% overload for 1 minute. Positive displacement pumps have constant torque (heavy duty) characteristics; therefore, requiring 150% overload for 1 minute.

Some pump manufacturers require lower RPM motors for their pumps which at a given horsepower will require more current than a typical 4-pole, 1800 RPM motor. The AC drive can have to be sized larger (de-rated) than the motor horsepower based on motor Full Load Amperes (FLA).

Fan applications typically use 1800 RPM motors, but motor FLA should be reviewed to verify that de-rating of the AC drive is not required. Fan applications should be reviewed for desired stopping times and inertia to determine if dynamic braking is required to prevent nuisance over-voltage tripping of the AC drive.

Food and Beverage Industry

Typically, AC drives in the Food and Beverage industry include the control of pumps, agitators, conveyors, and basic material handling. Most deal with large quantities of materials with tolerances in the seconds as opposed to msecs.

Coordination is only required on the fill/finish areas for items like labeling and packaging, and have low horsepower requirements. These applications require speed and torque regulation based on the application requirements. Demand, burden, and load in the dough mixing industry has lent to specific vendor preferences in the past (for example, technical drive variances can effect product quality).

Review the motor cable distances. The use of an appropriate output device can be required based on cable distance, motor insulation, and desired operating carrier frequency (PWM Frequency). See Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, for details on motor cable length restrictions.

Forest Products and Converting Industry

Typically, AC drives in the Forest Products/Converting industries include the control of web applications. These applications require speed and torque regulation based on the type of web process. In certain converting applications, such as Cut to Length, the knife drive experiences high cyclic loading. In extreme cases, some applications require the drive to deliver a very high motoring load, and then switch to a very high regenerative load, within a brief period of time. In this situation, perform a complete duty cycle analysis when selecting the drive system components.

Review the motor cable distances. The use of an appropriate output device can be required based on cable distance, motor insulation, and desired operating carrier frequency (PWM Frequency). See Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, for details on motor cable length restrictions.

Mining and Steel Industry

Typically, AC drives in the Mining and Steel industry include the control of conveyors and presses. These applications require speed and torque regulation based on the application.

Review the motor cable distances. The use of an appropriate output device can be required based on cable distance, motor insulation, and desired operating carrier frequency (PWM Frequency). See Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, for details on motor cable length restrictions.

Tire Manufacturing Industry

Typically, AC drives in the Tire Manufacturing industry include the control of extruders and conveyors. These applications require speed and torque regulation based on the application requirements. Drives that are exposed to the tire manufacturing process, not mounted in a control house, are exposed to carbon black. The most common use of carbon black is as a pigment and reinforcing phase in automobile tires. Carbon black conducts heat away from the tread and belt area of the tire which reduces thermal damage, and helps to maintain the reliability of the tire life. Carbon black is conductive and effects electronic circuits and assemblies by reducing the resistivity of the air and the clearances around devices such as surface-mount components, as well as high-voltage assemblies such as bus bars.

Review the motor cable distances. The use of an appropriate output device can be required based on cable distance, motor insulation, and desired operating carrier frequency (PWM Frequency). See Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, for details on motor cable length restrictions.

For more information on the tire and rubber industry see the Control System Packaging for Corrosion Mitigation Design and Installation Guideline, publication TIRE-RM001.

Water and Waste Water Industry

Typical applications for AC drives in Water/Waste Water include the control of pumps and fans. These applications are normally variable torque (normal duty) rated and only require 115% overload for 1 minute. Positive displacement pumps have constant torque (heavy duty) characteristics; therefore, requiring 150% overload for 1 minute.

Some pump manufacturers require lower RPM motors for their pumps which at a given horsepower will require more current than a typical 4-pole, 1800 RPM motor. The AC drive can have to be sized larger (de-rated) than the motor horsepower based on motor Full Load Amperes (FLA).

Fan applications typically use 1800 RPM motors, but motor FLA should be reviewed to verify that de-rating of the AC drive is not required. Fan

applications should be reviewed for desired stopping times and inertia to determine if dynamic braking is required to prevent nuisance over-voltage tripping of the AC drive.

Review the motor cable distances. The use of an appropriate output device can be required based on cable distance, motor insulation, and desired operating carrier frequency (PWM Frequency). See Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001, for details on motor cable length restrictions.

For more information on the Water and Wastewater industry see the Control System Packaging for Corrosion Mitigation Design and Installation Guideline, publication WWW-WP001.

Notes:

Marine and Offshore Industry

The marine and offshore industry has a number of different conditions to be aware of due to the environment where it operates. This section describes some of the things of which to be aware.

Typical Environmental Conditions

In the Marine and Offshore industry the AC drive can be installed either indoor (controlled), indoor (uncontrolled or ventilated), or outdoor (above deck). With an outdoor and indoor (uncontrolled) installation, the environmental conditions that can be present are:

- Salt air
- Moisture and/or humidity
- Splashing seawater (above deck)
- High windows (above deck)
- Solar heating (above deck)
- UV light

Typical Hazardous Areas

In the marine and offshore industry the AC drive must comply with IEC Publication 60079, or other recognized standards, if it is installed in a hazardous area. The following are examples of protective standards for hazardous areas.

- Intrinsically safe type (Ex i) (not suitable for high power)
- Flameproof (explosion-proof) type (Ex d)
- Increased safety type (Ex e)
- Pressurized or purged type (Ex p)

Consideration must be given to the flammability group and the temperature class of the equipment for suitability for the intended hazardous area (see IEC Publication 60079-20). The following are examples of typical hazardous areas:

- Paint stores
- Battery rooms
- Oxygen-acetylene storage room
- Helicopter refueling facilities
- Other spaces defined by specification
- Areas defined by SVR, Part 5C, or the American Bureau of Shipping (ABS) rules for Offshore Drilling Units and/or Floating Production Units

Shielding by Enclosures

The degree of protection required by shipboard enclosure is established by ABS Steel Vessel Rules (or other rules having jurisdiction). Table 6 represents typical locations and their required levels of protection. The protection ratings are detailed in Abridged Descriptions of IEC Enclosure Test Requirements on page 11.

Table 6 - Minimum Degree of Protection (2006)

Example of Location	Condition of Location	Switchboards, Distribution Boards, Motor Control Centers, and Controllers	Generators	Motors	Transformers, Converters	Lighting Fixtures	Heating Appliances	Accessories(1)
Dry accommodation space	Danger of touching live parts only	IP20	–(2)	IP20	IP20	IP20	IP20	IP20
Dry control rooms(3)		IP20	–	IP20	IP20	IP20	IP20	IP20
Control rooms	Danger of dripping liquid and/or moderate mechanical damage	IP22	–	IP22	IP22	IP22	IP22	IP22
Machinery spaces above floor plates(4)		IP22	IP22	IP22	IP22	IP22	IP22	IP44
Steering gear rooms		IP22	IP22	IP22	IP22	IP22	IP22	IP44
Refrigerating machinery room		IP22	–	IP22	IP22	IP22	IP22	IP44
Emergency machinery room		IP22	IP22	IP22	IP22	IP22	IP22	IP44
General store rooms		IP22	–	IP22	IP22	IP22	IP22	IP22
Pantries		IP22	–	IP22	IP22	IP22	IP22	IP44
Provision rooms		IP22	–	IP22	IP22	IP22	IP22	IP22
Bathrooms and showers	Increased danger of liquid an/or mechanical damage	–	–	–	–	IP34	IP44	IP55
Machinery spaces below floor plates		–	–	IP44	–	IP34	IP44	IP55(5)
Closed fuel oil or lubricating oil separator rooms		IP44	–	IP44	–	IP34	IP44	IP55(5)
Ballast pump rooms	Increased danger of liquid and mechanical damage	IP44	–	IP44	IP44	IP34	IP44	IP55
Refrigerated rooms		–	–	IP44	–	IP34	IP44	IP55
Galleys and laundries		IP44	–	IP44	IP44	IP34	IP44	IP44
Shaft or pipe tunnels in double bottom	Danger of liquid spray, presence of cargo dust, serious mechanical damage, and/or aggressive fumes	IP55	–	IP55	IP55	IP55	IP55	IP56
Holds for general cargo		–	–	–	–	IP55	–	IP55
Open decks	Exposure to heavy seas	IP56	–	IP56	–	IP55	IP56	IP56
Bilge wells	Exposure to submersion	–	–	–	–	IPX8	–	IPX8

(1) "Accessories" include switches, detectors, junction boxes, etc.
(2) Empty spaces shown with "–" indicate installation of electrical equipment is not recommended.
(3) For the purpose of this Table, the wheelhouse can be categorized as a "dry control room" and consequently, the installation of IP20 equipment would suffice therein provided that: (a) the equipment is located as to preclude being exposed to steam, or dripping/spraying liquids emanating from pipe flanges, valves, ventilation ducts and outlets, etc., installed in its vicinity, and (b) the equipment is placed to preclude the possibility of being exposed to sea or rain.
(4) (2006) See ABS Publication Rules for Building and Classing Steel Vessel Rules (2011), Part 4, Vessel Systems and Machinery, 4-8-3/1.11.2, where the equipment is located within areas protected by local fixed pressure water-spraying or water-mist fire extinguishing system and its adjacent areas.
(5) Socket outlets are not to be installed in machinery spaces below the floor plate, enclosed fuel and lubricating oil separator rooms or spaces requiring certified safe equipment.

Protecting Electronic Modules During Installation

Because of direct exposure to the process environment during installation, the electronic modules can be exposed to contaminants and are susceptible to corrosion damage. After this exposure, failures can occur even after the electronic modules are sealed within enclosures. To minimize the potential for failure, follow these precautions.

- Complete the construction and wiring (as much as possible) of the control rooms before the modules are unpacked.
- Minimize the time modules remain in an unprotected area.
- Always use protective bags for module storage.
- Keep doors to control rooms and enclosures closed unless opening the door is a necessity.

Power Distribution

You must evaluate and configure the power distribution systems to provide optimum performance for the AC drive. See System Configurations and Grounding below.

For more information, see the Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001.

System Configurations and Grounding

The type of transformer and the connection configuration feeding a drive plays an important role in the performance and safety of the drive. The following is a brief description of some of the more common configurations and a discussion of their qualities and differences.

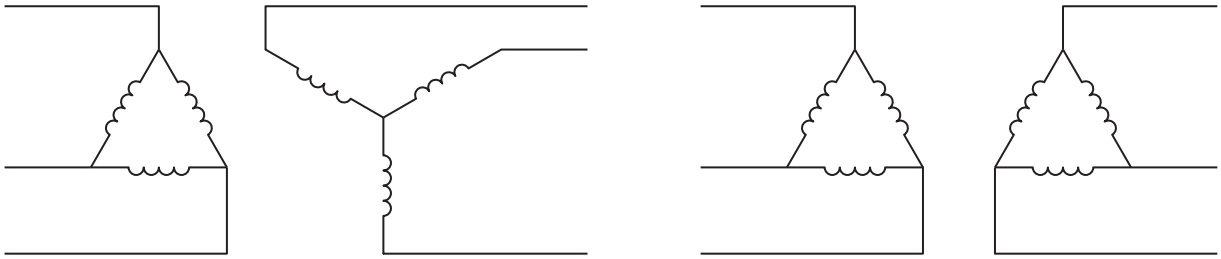
Ungrounded Power

For shipboard applications the power system is typically ungrounded (3-wire). This allows for continuity of service under single line-to-ground fault conditions, particularly in distribution systems supplying critical service loads to the ship. Ungrounded systems shall require the removal of the drives MOV jumpers and Y caps. To avoid damage to the drive under spike voltage conditions, use an isolation transformer. Provide a means to continuously monitor and indicate the state of the insulation-to-ground for drives used for electric propulsion systems and emergency power systems, and drives that are isolated by transformers, motor-generators, or other devices.

Solidly grounded designs should be limited to systems supplying noncritical loads, such as normal lighting, galley circuits, etc.

WARNING: The hull of a vessel must not carry current as a conductor. Failure to remove the jumpers in the drive can result in holes in the hull of the vessel.

Ungrounded Secondary



Application and Control

Typically, AC drives in the Marine and Offshore industry include the control of crane applications, winch applications, and secondary propulsion systems.

System Design and Implementation Considerations

- To determine sizing of your generator sets, perform a complete evaluation of the system demands for steady state, as well as peak loading and inrush conditions.
- For PWM AC Drive applications single point grounding where the VFD ground is preferred to be directly routed back to Wye of supply transformer or zig-zag transformer. (Check with local codes, marine, and MIL specifications.)
- When non-linear loads (such as AC adjustable speed drives) are part of the connected load, harmonics and power factor will also affect generator set sizing.
- To estimate Voltage Total Harmonic Distortion (V_THD) as a function of AC line side converter topology, consider these factors:
  - generator Z
  - number of parallel generator sets
  - single kVA oversize

  Low harmonic adjustable speed drive supplies can significantly reduce generator kVA oversizing.
- Systems powered by a local generator typically require more design considerations than systems powered by a large utility.
- Synchronous generators have a limited capability to absorb real or reactive power (leading), as well as harmonics.
- Generators produce harmonics. The pitch of the generator determines the frequency and level of the harmonics.
- Establish the single line for the system and define the load requirements prior to selecting a generator.
- Document and review operating scenarios and sequences of operation in regard to the different contingencies that can occur. This includes commissioning when the system is not fully functional, and therefore, operating in a non-standard mode.
- Include the drive and generator suppliers in system design and development from the beginning and throughout the project. Then if design changes occur, it will be easier for the drive and generator suppliers to make changes to help optimize the system.
- Non-linear loads (such as AC adjustable speed drives) require additional design and implementation consideration when applied on local generator supplies. The limited capacity and high reactance of these local sources exaggerate the effects that occur on all systems, but are significantly reduced on higher capacity, more diverse supplies.
- The use of radios on ships and cranes and radars aboard ships introduces the risk of electromagnetic interference (EMI) problems for PWM AC Drives which could become susceptible to an intense electromagnetic environment (EME) and malfunction. Additional hardening against electromagnetic environmental effects (E3) can be needed including EMI shielding of and bonding of cables, EMI shielded/bonded enclosures and equipment, use of high performance line filtering. For procedures and guidance to address these requirements, refer to publications:
  - MIL-STD-1310H Shipboard Bonding, Grounding, and other Techniques for Electromagnetic Compatibility, Electromagnetic Pulse (EMP) Mitigation, and Safety
  - DNV Commercial Ship Guidelines for EMC control CN45-1
  - IEEE 45.3-2012 IEEE Recommended Practice for Shipboard Electrical Installations - Systems Engineering

For more information, refer to the IEEE publication, Electrical System Design of Local Generator Applications Involving Adjustable Speed Drives.

Sample Drive Installation Requirements

These sample checklists can be used in different phases of a project (design, pre-install, and post-install) to help confirm that the installation is done per recommendations and requirements. See Appendix B for additional, industry-specific, recommendations and requirements.

Design Checklist

Checklist of common items to be considered when designing any system with our standard drives.

AC Supply Source

- ☐ Identify or select distribution transformer grounding and note how drive power jumpers should be configured
  - For unbalanced, ungrounded, or resistive grounded distribution systems:
    - Note to configure power jumpers in the open position or removed from the circuit
    - Consider adding alternate surge suppression in front of the drive (required for UL)
  - For solidly grounded distribution systems (preferred):
    - Note to configure power jumpers in the closed position or in circuit
  - For unknown systems:
    - Note to identify grounding and configure jumpers accordingly

Input Power Conditioning

- ☐ Verify that a Rockwell Automation™ 1321 type or equivalent Isolation Transformer (a grounded secondary supply voltage source) is installed.
- ☐ Verify that the Isolation Transformer kVA size does not exceed 10 times the kVA rating of the drive.
  - If the transformer exceeds 10 times the kVA rating of drives without DC Link Chokes or 20 times the kVA rating of drives with DC Link Chokes, add additional impedance in front of the drive (a line reactor is most common).
- ☐ Verify that the X0 on the secondary of the Isolation Transformer is solidly grounded (less than 1 Ω).
- ☐ Line reactors are required if an Isolation Transformer is not used. No device shall be wired between the line reactor (secondary side) and the drive.

Grounding and Bonding

- ☐ Verify that the paint is scraped away down to bare metal when mounting the Ground Bar.
- ☐ Verify that a ground wire is run from the drive (PE) ground terminal directly to the enclosure ground bar using specified gauge wire.
- ☐ Verify that a ground wire is run from the Motor **directly** to the Drive.
- ☐ Verify that multiple Sub-Plates are bonded together using braided metal straps.
- ☐ For Unbalanced, Ungrounded, or Resistive Grounded Distribution Systems:
  - Remove protective MOVs from the drive.
  - Remove Common Mode Capacitors from the drive.

Motor Cable Wiring

- ☐ Verify that the motor cable is the shielded type.
- ☐ The motor cable shield must be connected at both the Drive end and at the Motor end.
- ☐ Verify that the mechanical brake cable shield is **terminated to the enclosure ground bar**—NOT to the drive.
- ☐ Verify that motor cable lengths adhere to the specifications outlined in Appendix A of publication DRIVES-IN001

Encoder Feedback Signal Wiring – Rockwell Automation Recommended Shielding Technique

- ☐ Verify the type of Encoder Cable being used.
- ☐ Verify that Encoder Cable wiring is NOT within 304 mm (12 in.) of motor power wiring and/or motor brake wiring within the enclosure.
- ☐ Verify that Encoder Cable wiring outside the enclosure is run in raceways using dividers or with separate conduit runs.
- ☐ Verify that the shield is terminated at the drive end only.

Dynamic Brakes

- ☐ Verify that the dynamic brake is installed and wired to (BR+) and (BR-) on the drive.
- ☐ Verify that the dynamic brake cable type is twisted-pair.

Wire Routing

- ☐ Verify that there is separation between High and Low voltage wiring, and that wires cross at 90° angles.

Surge Suppression

- ☐ Verify that Surge Suppressors are installed on all coils, including contactors, solenoids, relays, and brake coils, to reduce transients that can interfere with the drives.

Environmental Considerations

- ☐ Equipment installation must meet the basic environmental requirements as outlined in Chapter 1, and the industry-related installation considerations outlined in Chapter 2 of this manual. See the product manual for specific installation requirements.

Pre-Installation Checklists

Items to check before installation of standard drives.

AC Supply Source Input Power Conditioning

- ☐ Confirm distribution transformer grounding and drive power jumper configuration
  - For unbalanced, ungrounded, or resistive grounded distribution systems:
    - Configure power jumpers in the open position or removed from the circuit
  - For solidly grounded distribution systems:
    - Configure power jumpers in the closed position or in circuit
- ☐ Identify the distribution transformer kVA size.
  - If the transformer exceeds 10 times the kVA rating of drives without DC Link Chokes or 20 times the kVA rating of drives with DC Link Chokes, add additional impedance in front of the drive (a line reactor is most common).
  - The kVA should at least meet the full load kVA of the rating of the drive on a non-Regen drive.
  - For PowerFlex™ 755TL/TR/TM drives, the supply system kVA must be equal to or greater than the product-related kW, and the system impedance must be less than 10%. System impedance is calculated as
- ☐ {System Impedance - (PowerFlex 755T kVA / Transformer kVA) x Transformer % impedance}
- ☐ Validate supplemental equipment that will be on the same power as the drive (PFCCs, other switching devices, passive harmonic filters)
  - Implement necessary isolation as required

Surge Suppression

- ☐ Identify all coils, including contactors, solenoids, relays, and brake coils, so surge suppressors can be installed to reduce transients that can interfere with the drives (for both control and line power, for example, mechanical brakes operating at 480V).

Grounding and Bonding

- ☐ Verify that the paint is scraped away down to bare metal when mounting the Ground Bar.
- ☐ Verify that a ground wire is run from the drive (PE) ground terminal directly to the enclosure ground bar using specified gauge wire.
- ☐ Verify that a ground wire is run from the Motor **directly** to the Drive.
- ☐ Verify that multiple Sub-Plates are bonded together using braided metal straps.
- ☐ Verify that PE grounds are located properly.
  - This has the input power ground that is located on the terminal/connection closer to the input power wiring and the motor cable ground that is located on the terminal/connection closer to the output power wiring.

Mounting Considerations and Environment

- ☐ Equipment installation must meet the basic environmental requirements as outlined in Chapter 1 and Chapter 2 of this manual. See the product manual for specific installation requirements.
- ☐ Ensure that the minimum mounting clearances will be met on the drive.
- ☐ Ensure that drive enclosure rating will protect the drive from relevant physical contaminants and corrosive gases
  - IP00, IP20, and NEMA/UL Open Type PowerFlex Series drives must be mounted in a clean, dry location. Contaminants such as oils, corrosive vapors, and abrasive debris must be kept out of the enclosure. These enclosures are intended for indoor use primarily to provide a degree of protection against contact with enclosed equipment. These enclosures offer no protection against airborne contaminants.
  - IP54 enclosures provide a degree of protection from dirt, dust, oil, and other noncorrosive material, as well as splashing water.

Control and Signal Cabling

- ☐ Verify that there is separation between High and Low voltage wiring, and that wires cross at 90° angles.
  - See the table in the Wire Routing section of Chapter 4 in the Wiring and Grounding for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001.

Dynamic Brakes

- ☐ Verify that the dynamic brake is installed and wired to (BR+) and (BR-) on the drive.
- ☐ Verify that the dynamic brake cable type is twisted-pair.
- ☐ Verify that dynamic brake cable length will not exceed recommendations based on drive frame size

Motor Cable Wiring

- ☐ Verify that the motor cable is the shielded type.
- ☐ The motor cable shield must be connected at both the Drive end and at the Motor end.
- ☐ Verify that the mechanical brake cable shield is **terminated to the enclosure ground bar**—NOT to the drive.
- ☐ Verify that motor cable lengths adhere to the specifications outlined in Appendix A of publication DRIVES-IN001 to ensure that motor insulation rating will be sufficient for cable length. If not, implement on of the solutions that are recommended in the tables.

Encoder Feedback Signal Wiring – Rockwell Automation Recommended Shielding Technique

- ☐ Verify the type of Encoder Cable being used.
- ☐ Verify that Encoder Cable wiring is NOT within 304 mm (12 in.) of motor power wiring and/or motor brake wiring within the enclosure.
- ☐ Verify that Encoder Cable wiring outside the enclosure is run in raceways using dividers or with separate conduit runs.
- ☐ Validate encoder type is compatible with feedback module
- ☐ Verify that the shield is terminated at the drive end only.

Post Installation Checklists

Items to recheck after installation of standard drives.

AC Supply Source

- ☐ Confirm distribution transformer grounding and drive power jumper configuration
  - For unbalanced, ungrounded, or resistive grounded distribution systems:
    - Configure power jumpers in the open position or removed from the circuit
  - For solidly grounded distribution systems:
    - Configure power jumpers in the closed position or in circuit

Input Power Conditioning

- ☐ Identify the distribution transformer kVA size.
  - If the transformer **exceeds** 10 times the kVA rating of drives without DC Link Chokes or 20 times the kVA rating of drives with DC Link Chokes, add additional impedance in front of the drive (a line reactor is most common).
  - The kVA should at least meet the full load kVA of the rating of the drive on a non-Regen drive.
  - For PowerFlex 755TL/TR/TM drives, the supply system kVA must be equal to or greater than the product-related kW, and the system impedance must be less than 10%. System impedance is calculated as:

    {System Impedance - (PowerFlex 755T kVA / Transformer kVA) x Transformer % impedance}
- ☐ Validate supplemental equipment that will be on the same power as the drive (PFCCs, other switching devices, passive harmonic filters)
  - Implement necessary isolation as required

Surge Suppression

- ☐ Verify that Surge Suppressors are installed on all coils, including contactors, solenoids, relays, and brake coils, to reduce transients that can interfere with the drives (for both control and line power, that is mechanical brakes operating at 480V).

Grounding and Bonding

- ☐ Verify that the paint is scraped away down to bare metal when mounting the Ground Bar.
- ☐ Verify that a ground wire is run from the drive (PE) ground terminal directly to the enclosure ground bar using specified gauge wire.
- ☐ Verify that a ground wire is run from the Motor **directly** to the Drive.
- ☐ Verify that multiple Sub-Plates are bonded together using braided metal straps.
- ☐ Verify that PE grounds are located properly.
  - This has the input power ground that is located on the terminal/connection closer to the input power wiring and the motor cable ground that is located on the terminal/connection closer to the output power wiring.

Mounting Considerations and Environment

- ☐ Verify that the ambient temperature will not exceed the drive rating unless proper derating is applied.
- ☐ Ensure that the minimum mounting clearances will be met on the drive.
- ☐ Ensure that drive enclosure rating will protect drive from relevant physical contaminants and corrosive gases:
  - IP00, IP20, and NEMA/UL Open Type PowerFlex Series drives must be mounted in a clean, dry location. Contaminants such as oils, corrosive vapors, and abrasive debris must be kept out of the enclosure. These enclosures are intended for indoor use primarily to provide a degree of protection against contact with enclosed equipment. These enclosures offer no protection against airborne contaminants.
  - IP54 enclosures provide a degree of protection from dirt, dust, oil, and other noncorrosive material as well as splashing water.

Control and Signal Cabling

- ☐ Verify that there is separation between High and Low voltage wiring, and that wires cross at 90° angles.
  - See the table in the Wire Routing section of Chapter 4 in the Wiring and Grounding for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001.

Dynamic Brakes

- ☐ Verify that the dynamic brake is installed and wired to (BR+) and (BR-) on the drive.
- ☐ Verify that the dynamic brake cable type is twisted-pair.
- ☐ Verify that dynamic brake cable length will not exceed recommendations based on drive frame size

Motor Cable Wiring

- ☐ Verify that the motor cable is the shielded type.
- ☐ The motor cable shield must be connected at both the Drive end and at the Motor end.
- ☐ Verify that the mechanical brake cable shield is **terminated to the enclosure ground bar**—NOT to the drive.
- ☐ Verify that motor cable lengths adhere to the specifications outlined in Appendix A of publication DRIVES-IN001 to confirm motor insulation rating is sufficient for the cable length. If not, implement one of the solutions that are recommended in the tables.

Encoder Feedback Signal Wiring – Rockwell Automation Recommended Shielding Technique

- ☐ Verify the type of Encoder Cable being used.
- ☐ Verify that Encoder Cable wiring is NOT within 304 mm (12 in.) of motor power wiring and/or motor brake wiring within the enclosure.
- ☐ Verify that Encoder Cable wiring outside the enclosure is run in raceways using dividers or with separate conduit runs.
- ☐ Validate encoder type is compatible with feedback module
- ☐ Verify that the shield is terminated at the drive end only.

Sample Requirements and Enclosure Specifications for Specific Industry Types

This section contains sample checklists to help you prepare industry-specific information for installation of drives for selected industries. Requirements that are common to enclosures and covered in other parts of this manual also apply to these enclosures. Information on other industries, which do not have specific enclosure information for this list, are described in other parts of this manual. Industries that are not listed specifically in this appendix and covered in the rest of this manual include: Chemical/Specialty Chemical, Food and Beverage, Marine and Offshore, Tire Manufacturing, and Water/Waste Water industry. As always, these are not comprehensive lists and are meant to help you consider the requirements for your specific industry and location.

Automotive Industry

In addition to the items that apply to all standard drives (see Appendix A), the following is a sample of the information that can be attached to an Automotive Manufacturer's RFQ or Purchase Order to a machine supplier, panel builder, or system integrator to help confirm that the supplier follows the recommendations that are presented in this document. Details for your specific location can vary.

Enclosure Construction

- All enclosures shall meet or exceed NEMA 12 for North America or IP54 for all other regions.

Welded

- Welded IP54 / NEMA 12 enclosures are acceptable for all applications and areas.
- Enclosures shall be made of cold rolled steel, painted with multiple layers, including primer and finish.
- Welds must be continuous on all seams, cleaned, and ground smooth before painting.
- The enclosure must have a solid bottom and top.

Grounding

- The ground bar shall be one solid piece and located along the bottom of the enclosure.
- All enclosures must be designed to meet the requirements of NFPA79 and the latest National Electrical Code.
- Sensitive electronic devices require supplemental grounding techniques to reduce the effects of EMI
- A braided copper bonding jumper shall be installed to bond the main enclosure panel to any enclosure doors to be compliant with NFPA 70 Chapter 17.
- All ground connection points to the enclosure shall have the paint removed at the point of contact.

Frame and Panel

- The enclosure must have solid plates installed on the top and bottom.
- Solid is preferable. Multi piece gland plates can be acceptable as long as they are properly sealed.
- All ferrous metal parts on the enclosure shall be painted or plated to help prevent rust.

Cooling

- Heat calculations must be performed and submitted with approval drawings for each enclosure.
- Acceptable cooling methods for include:
  - Conductive heat dissipation shall be used if the heat generated can be effectively transmitted through the sheet metal of the enclosure.
  - Heat exchangers or air conditioners shall be used to remove heat when conductive dissipation is not sufficient.

Forest Products/Converting (Pulp Paper Products) Industry

In addition to the items that apply to all standard drives (see Appendix A), the following is a sample of the information that can be attached to a Paper Manufacturer's RFQ or Purchase Order to a machine supplier, panel builder, or system integrator to help ensure that the supplier follows the recommendations that are presented in this document. Details for your specific location can vary.

Enclosure Construction

- All enclosures shall meet or exceed IP54. IP54 design that circulates external air through IP54 rated filters is NOT acceptable. These include enclosures rated IP55, IP62, IP64, IP67, for example.
- All cable entry points shall be designed to use cord grips or cable entry management systems that seal each cable or conductor to meet or exceed an IP54 rating.
- All conduit / wireway entries shall be designed to be sealed with fire block or other conduit seal compound.
- Silicon-based sealants shall not be used.

Welded

- Welded IP54 / NEMA 12 enclosures are acceptable for all applications and areas.
- Enclosures shall be made of cold rolled steel, painted with multiple layers, including corrosion-resistant primer and finished with a baked-on paint (for example, enamel, polyester).
- Welds must be continuous on all seams, cleaned, and ground smooth before painting.
- The enclosure must have a solid bottom and top.

Frame and Panel

- IP54 rated frame and panel enclosures, Rittal, Hoffman Proline 2, or similar, are acceptable in locations where exposure to mechanical damage from moving vehicles such as, tow motors, fork trucks, or carts is not possible.
- The enclosure must have solid plates installed on the top and bottom.
- Solid is preferable. Multi piece gland plates can be acceptable as long as they are properly sealed.

Gaskets

- Gaskets must be neoprene rubber for chemical and acid / base resistance. Gaskets must be applied in a channel to help ensure that the seal remains in place.

- Spray-on foam gasket material, as is used in many modular enclosure systems and some welded solutions, is acceptable if it is a material that is rated for corrosive gas rich environments.
- Silicone rubber-based gasket material shall not be used.

Cooling

- Heat calculations must be performed and submitted with approval drawings for each enclosure.
- Acceptable cooling methods for include:
  - Conductive heat dissipation shall be used if the heat generated can be effectively transmitted through the sheet metal of the enclosure.
  - Heat exchangers or air conditioners shall be used to remove heat when conductive dissipation is not sufficient. The heat exchangers / air conditioners must be sealed so that air external to the enclosure is not mixed with internal air.
  - Heat exchanger / air conditioners shall be conform coated IP66 / NEMA 4 versions of these units.

Marine and Offshore Industry

The marine and offshore industry has a number of requirements in addition to those described in Appendix A. See Chapter 4 for detailed information.

Metals Industry

In addition to the items that apply to all standard drives (see Appendix A: Sample Drive Installation Requirements, the following is a sample of the information that can be attached to a Metal Manufacturer's RFQ or Purchase Order to a machine supplier, panel builder, or system integrator to help ensure that the supplier follows the recommendations that are presented in this document. Details for your specific location can vary.

Enclosure Construction

- All enclosures shall meet or exceed NEMA12. Additional filtering or the use of a positive pressure system is also required to help protect against particulate contaminants.
- All cable entry points shall be designed to use cord grips or cable entry management systems that seal each cable or conductor to meet or exceed a NEMA12 rating.
- All conduit / wireway entries shall be designed to be sealed with fire block or other conduit seal compound.

Welded

- Welded NEMA 12 enclosures are acceptable for all applications and areas.
- Enclosures shall be made of cold rolled steel, painted with multiple layers, and finished with a baked-on paint (for example, enamel, polyester).
- Welds must be continuous on all seams, cleaned, and ground smooth before painting.
- The enclosure must have a solid bottom and top.

Frame and Panel

- NEMA 12 rated frame and panel enclosures, Rittal, Hoffman Proline 2, or similar, are acceptable in locations where exposure to mechanical damage from moving vehicles such as, tow motors, fork trucks, or carts is not possible.
- The enclosure must have solid plates installed on the top and bottom.
- Solid is preferable. Multi piece gland plates can be acceptable as long as they are properly sealed.

Gaskets

- Gaskets must be aligned with a NEMA 12 rating.

Cooling

- Heat calculations must be performed and submitted with approval drawings for each enclosure.
- Acceptable cooling methods for include:
  - Conductive heat dissipation shall be used if the heat generated can be effectively transmitted through the sheet metal of the enclosure.
  - Heat exchangers or air conditioners shall be used to remove heat when conductive dissipation is not sufficient. The heat exchangers / air conditioners must be either filtered or bringing in external air.

Mining Process Products

In addition to the items that apply to all standard drives (see Appendix A: Sample Drive Installation Requirements), the following is a sample of the information that can be attached to a Mining Organization's RFQ or Purchase Order to a machine supplier, panel builder, or system integrator to help ensure that the supplier follows the recommendations that are presented in this document. This sample is focused on the Process aspect of a mine. Details for your specific location can vary.

Enclosure Construction

- All enclosures shall meet or exceed IP12. Additional filtering or the use of a positive pressure system is also required to help protect against particulate contaminants.
- All cable entry points shall be designed to use cord grips or cable entry management systems that seal each cable or conductor to meet or exceed an IP12 rating.
- All conduit / wireway entries shall be designed to be sealed with fire block or other conduit seal compound.

Welded

- Welded IP12 enclosures are acceptable for all applications and areas.
- Enclosures shall be made of cold rolled steel, painted with multiple layers, and finished with a baked-on paint (for example, enamel, polyester).
- Welds must be continuous on all seams, cleaned, and ground smooth before painting.
- The enclosure must have a solid bottom and top.

Frame and Panel

- IP12 rated frame and panel enclosures, Rittal, Hoffman Proline 2, or similar, are acceptable in locations where exposure to mechanical damage from moving vehicles such as, tow motors, fork trucks, or carts is not possible.
- The enclosure must have solid plates installed on the top and bottom.
- Solid is preferable. Multi piece gland plates can be acceptable as long as they are properly sealed.

Gaskets

- Gaskets must be made of material to meet the IP12 rating.

Cooling

- Heat calculations must be performed and submitted with approval drawings for each enclosure.
- Acceptable cooling methods for include:
  - Conductive heat dissipation shall be used if the heat generated can be effectively transmitted through the sheet metal of the enclosure.
  - Heat exchangers or air conditioners shall be used to remove heat when conductive dissipation is not sufficient.
  - Proper filtering or positive air pressure must be used on any air exchange that will occur for cooling.

Oil, Gas, and Chemical Products

In addition to the items that apply to all standard drives (see Appendix A: Sample Drive Installation Requirements), the following is a sample of the information that can be attached to an Oil/Gas/Chemical Producer's RFQ or Purchase Order to a machine supplier, panel builder, or system integrator to help ensure that the supplier follows the recommendations that are presented in this document. Details for your specific location can vary.

Enclosure Construction

- All enclosures shall meet or exceed IP54. IP54 design that circulates external air through IP54 rated filters is NOT acceptable. These include enclosures rated IP55, IP62, IP64, IP67, for example.
- All cable entry points shall be designed to use cord grips or cable entry management systems that seal each cable or conductor to meet or exceed an IP54 rating.
- All conduit / wireway entries shall be designed to be sealed with fire block or other conduit seal compound.
- Silicon-based sealants shall not be used.
- Enclosures shall meet IEEE C37.20.7 for arc resistance
- Enclosures shall be certified to meet Class 1 Div 1 for hazardous locations
- Enclosures and equipment shall have Seismic certification
- Enclosures shall meet marine standards ABS, DNV, and Lloyd's

Welded

- Welded IP54 / NEMA 12 enclosures are acceptable for all applications and areas.
- Enclosures shall be made of cold rolled steel, painted with multiple layers, including corrosion-resistant primer and finished with a baked-on paint (for example, enamel, polyester).
- Welds must be continuous on all seams, cleaned, and ground smooth before painting.
- The enclosure must have a solid bottom and top.

Frame and Panel

- IP54 rated frame and panel enclosures, Rittal, Hoffman Proline 2, or similar, are acceptable in locations where exposure to mechanical damage from moving vehicles such as, tow motors, fork trucks, or carts is not possible.
- The enclosure must have solid plates installed on the top and bottom.
- Solid is preferable. Multi piece gland plates can be acceptable as long as they are properly sealed.

Gaskets

- Gaskets must be neoprene rubber for chemical and acid / base resistance. Gaskets must be applied in a channel to help ensure that the seal remains in place.

- Spray-on foam gasket material, as is used in many modular enclosure systems and some welded solutions, is acceptable if it is a material that is rated for corrosive gas rich environments.
- Silicone rubber-based gasket material shall not be used.

Temperature Control

- Heat calculations must be performed and submitted with approval drawings for each enclosure.
- Acceptable cooling methods for include:
  - Conductive heat dissipation shall be used if the heat generated can be effectively transmitted through the sheet metal of the enclosure.
  - Heat exchangers or air conditioners shall be used to remove heat when conductive dissipation is not sufficient. The heat exchangers / air conditioners must be sealed so that air external to the enclosure is not mixed with internal air.
  - Heat exchanger / air conditioners shall be conform coated IP66 / NEMA 4 versions of these units.
  - Heating elements shall be fused and sized to heat the enclosure when the equipment is not producing heat from -50C up to the equipment's minimum operating temperature.

Open Pit Mining Products

In addition to the items that apply to all standard drives (see Appendix A: Sample Drive Installation Requirements), the following is a sample of the information that can be attached to a Mining Organization's RFQ or Purchase Order to a machine supplier, panel builder, or system integrator to help ensure that the supplier follows the recommendations that are presented in this document. This sample is focused on an Open Pit application. Details for your specific location can vary.

Enclosure Construction

- All enclosures shall meet or exceed IP12. Additional filtering or the use of a positive pressure system is also required to protect against particulate contaminants.
- All cable entry points shall be designed to use cord grips or cable entry management systems that seal each cable or conductor to meet or exceed an IP12 rating.
- All conduit / wireway entries shall be designed to be sealed with fire block or other conduit seal compound.
- The overall enclosure and gasketing construction must made of material that is built to withstand UV exposure.

Welded

- Welded IP12 enclosures are acceptable for all applications and areas.
- Enclosures shall be made of cold rolled steel, painted with multiple layers, and finished with a baked-on paint (for example, enamel, polyester).
- Welds must be continuous on all seams, cleaned, and ground smooth before painting.
- The enclosure must have a solid bottom and top.

Frame and Panel

- IP12 rated frame and panel enclosures, Rittal, Hoffman Proline 2, or similar, are acceptable in locations where exposure to mechanical damage from moving vehicles such as, tow motors, fork trucks, or carts is not possible.
- The enclosure must have solid plates installed on the top and bottom.
- Solid is preferable. Multi piece gland plates can be acceptable as long as they are properly sealed.

Gaskets

- Gaskets must be made of material to withstand the temperature demands and UV exposure. Gaskets must be applied in a channel to help ensure that the seal remains in place.
- Spray-on foam gasket material, as is used in many modular enclosure systems and some welded solutions, is acceptable if it is a material that is rated for the necessary temperature and UV environments.

Cooling

- Heat calculations must be performed and submitted with approval drawings for each enclosure.
- Acceptable cooling methods for include:
  - Conductive heat dissipation shall be used if the heat generated can be effectively transmitted through the sheet metal of the enclosure.
  - Heat exchangers or air conditioners shall be used to remove heat when conductive dissipation is not sufficient.
  - Proper filtering or positive air pressure must be used on any air exchange that will occur for cooling.
  - Heating elements shall be fused and sized to heat the enclosure when the equipment is not producing heat from -40C up to the equipment's minimum operating temperature.

Notes:

Numerics

A

C

D

E

I

N

P

R

Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
Wiring and Grounding Guidelines for Pulse Width Modulated (PWM) AC Drives Installation Instructions, publication DRIVES-IN001	Provides the basic information needed to properly wire and ground Pulse Width Modulated (PWM) AC drives.
Conformal Coating for Variable Speed Drives, publication DRIVES-WP021	Provides information about conformal coating on the Printed Circuit Boards (PCBs), which protects components with micro lead spacings. Coated PCB is for the protection of the micro lead components that are vulnerable to dust and moisture build up, which can result in conductive paths.
Control System Packaging for Corrosion Mitigation Design and Installation Guideline, publication TIRE-RM001.	Provides guidelines for the use of electronics or automation equipment in the tire and rubber industry with respect to the protection of the product from corrosive gases and contaminants that are present in the manufacturing environment.
Control System Packaging for Corrosion Mitigation White Paper, publication WWW-WP001.	Provides guidelines for the use of Rockwell Automation products in the water/wastewater industry with respect to attempting to protect the product from corrosive gases that are present in the manufacturing environment.
EtherNet/IP Network Devices User Manual, ENET-UM006	Describes how to configure and use EtherNet/IP devices to communicate on the EtherNet/IP network.
Ethernet Reference Manual, ENET-RM002	Describes basic Ethernet concepts, infrastructure components, and infrastructure features.
System Security Design Guidelines Reference Manual, SECURE-RM001	Provides guidance on how to conduct security assessments, implement Rockwell Automation products in a secure system, harden the control system, manage user access, and dispose of equipment.
Industrial Components Preventive Maintenance, Enclosures, and Contact Ratings Specifications, publication IC-TD002	Provides a quick reference tool for Allen-Bradley industrial automation controls and assemblies.
Safety Guidelines for the Application, Installation, and Maintenance of Solid-state Control, publication SGI-1.1	Designed to harmonize with NEMA Standards Publication No. ICS 1.1-1987 and provides general guidelines for the application, installation, and maintenance of solid-state control in the form of individual devices or packaged assemblies incorporating solid-state components.
Safety Products Information, https://ab.rockwellautomation.com/Safety	Provides various products and information related to standards and safety.
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	Provides general guidelines for installing a Rockwell Automation industrial system.
Product Certifications website, rok.auto/certifications.	Provides declarations of conformity, certificates, and other certification details.

You can view or download publications at rok.auto/literature.

Rockwell Automation Support

Use these resources to access support information.

Technical Support Center	Find help with how-to videos, FAQs, chat, user forums, and product notification updates.	rok.auto/support
Knowledgebase	Access Knowledgebase articles.	rok.auto/knowledgebase
Local Technical Support Phone Numbers	Locate the telephone number for your country.	rok.auto/phonesupport
Literature Library	Find installation instructions, manuals, brochures, and technical data publications.	rok.auto/literature
Product Compatibility and Download Center (PCDC)	Download firmware, associated files (such as AOP, EDS, and DTM), and access product release notes.	rok.auto/pcdc

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Rockwell Automation maintains current product environmental compliance information on its website at rok.auto/pec.

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