Copley Controls
Ruggedized Drives Standards Guide

Copley Controls Corp.

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This page for notes.

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ABOUT THIS GUIDE

Overview and Scope

The purpose of this guide is three-fold:

1 To provide details on the rugged aspects of the R-Series amplifier design and construction.

2 To provide a detailed overview of standards conformance including an in-depth discussion of the rigorous R-Series qualification test protocol.

3 To provide application guidance including suggestions regarding which R-Series models are most appropriate for certain MIL electric power standards.

Related Documentation

For important setup and operation information, see the *CME 2 User Guide.*

For related information, see the Xenus XTL User Guide and the R-Series data sheets.

Users of the CANopen features should also read these Copley Controls documents:

- *CANopen Programmer's Manual*
- *CML Reference Manual*
- *Copley Motion Objects Programmer's Guide*

Also of related interest:

- *Copley Indexer 2 Program User's Guide* (describes use of Indexer Program to create motion control sequences)
- *Copley Controls ASCII Interface Programmer's Guide* (describes how to send ASCII format commands over an amplifier's serial bus to set up and control one or more amplifiers)
- *Copley Amplifier Parameter Dictionary*
- *Copley Camming User Guide*
- *Copley DeviceNet Programmer's Guide*

Information on Copley Controls Software can be found at:
http://www.copleycontrols.com/Motion/Products/Software/index.html

Comments

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Revision History

Revision	Date	DECO	Comments
1	June 2008	17764	Initial release.

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CHAPTER 1: INTRODUCTION

This chapter provides an overview of the R-Series rugged amplifiers, including its applications and construction. Contents include:

1.1: Overview

The Copley R-Series is a line of digital motor amplifiers designed to operate in harsh environments. An extension to Copley's proven Xenus and AccelNet amplifier families, the R-Series offers a comprehensive range of AC and DC powered amplifiers for brushless and brush motors in high power density panel-mount and PCB mount packages, as summarized here:

Xenus Panel					
Quad A/B Encoder	**Resolver**	**Sin/Cos Encoder**	**Continuous Current**	**Peak Current**	**Vac**
R10-230-18	R10-230-18-R	R10-230-18-S	6 A	18 A	100-240
R10-230-36	R10-230-36-R	R10-230-36-S	12 A	36 A	
R10-230-40	R10-230-40-R	R10-230-40-S	20 A	40 A	
Xenus Micro Panel					
R11-230-02	R11-230-02-R	R11-230-02-S	1 A	2 A	
R11-230-06	R11-230-06-R	R11-230-06-S	3 A	6 A	
R11-230-10	R11-230-10-R	R11-230-10-S	5 A	10 A	

Accelnet Panel				
Quad A/B Encoder	**Analog Encoder**	**Continuous Current (A)**	**Peak Current (A)**	**Vdc**
R20-055-18	R20-055-18-S	6	18	20-55
R20-090-09	R20-090-09-S	3	9	20-90
R20-090-18	R20-090-18-S	6	18	20-90
R20-090-36	R20-090-36-S	12	36	20-90
R20-180-09	R20-180-09-S	3	9	20-180
R20-180-18	R20-180-18-S	6	18	20-180
Accelnet Micro Panel				
R21-055-09	R21-055-09-S	3	9	20-55
R21--055-18	R21--055-18-S	6	18	20-55
R21--055-03	R21--055-03-S	1	3	20-90
R21-090-09	R21-090-09-S	3	9	20-90
R21-090-12	R21-090-12-S	6	12	20-90
Accelnet Module				
R22-055-18	R22-055-18-S	6	18	20-55
R22-090-09	R22-090-09-S	3	6	20-90
R22-180-09	R22-180-09-S	3	9	20-180
R22-180-18	R22-180-18-S	6	18	20-180
R22-180-20	R22-180-20-S	10	20	20-180
Accelnet Micro Module				
R-23-055-06		3	6	14-55
R-23-090-04		2	4	14-90

Because they share a common architecture with the standard Xenus and Accelnet amplifiers, the R-Series amplifiers offer a highly cost-effective alternative to full MIL spec amplifiers, providing qualification-test proven solutions for a wide range of harsh environment applications. Ruggedized to endure temperature extremes, high humidity, vibration and shock, the R-Series finds application in commercial off-the-shelf (COTS) military, nautical, aviation, oil refining, and vehicle based systems.

The R-Series uses the same set of software tools as Copley's commercial amplifiers. Our flagship Java-based CME2 configuration software allows for fast, intuitive amplifier setup, tuning, and debugging.

The amplifiers incorporate a range of command interfaces and communication channels for system integration flexibility. CANopen, an international standard for motion control, is proven in harsh environments. RS-232/422/485 interfaces enable control via ASCII commands.

Step/direction and analog velocity/current command interfaces are ideal for integration into traditional architectures.

Copley Controls Corporation has more that 25 years experience in the design and construction of motion control and high power amplifiers. Copley products are designed and manufactured in the United States in our Canton, MA facility. Copley is ISO 9001:2000 certified and all of our R-Series products are RoHS compliant.

1.2: R-Series Construction

1.2.1: Stability over Temperature

There are a number of key design features that distinguish the R-Series amplifiers from their commercial grade counterparts and allow them to operate reliably in harsh environments. The most common harsh environmental condition encountered in rugged applications is extreme temperature. Copley's commercial grade amplifiers are specified for an ambient operating temperature range of 0° C to +45° C. The R-Series amplifiers have been designed for operation in ambient temperatures ranging from -40° C to +70° C.

A number of component features allow the R-Series to achieve the wider operating temperature range. For instance, all R-Series amplifier components (semiconductors, passives, electromechanical components, etc.) are rated for at least -40° C to +85° C operation. In circuits where temperature extremes might otherwise affect performance or function, the R-Series also uses resistors and capacitors with excellent low temperature characteristics.

1.2.2: Moisture and Contamination Resistance

All circuit boards used in the R-Series amplifiers are conformal coated with Humiseal 1A33 polyurethane. This conformal coating provides exceptional resistance to moisture and contaminants which can cause unprotected boards to fail in exteme environments. Humiseal 1A33 polyurethane is MIL-I-46508C and IPC-CC-830 qualified and is well suited for printed circuit board applications. The conformal coating has excellent mechanical properties, complies fully with the RoHS directive, and is UL recognized.

1.2.3: Enhanced EMI Protection

All of Copley's commercial and R-Series amplifiers have been successfully tested to the commercial EMI/EMC standards required for CE marking. These standards include EN 5011:1998 and EN 61000-6-1:2001. EMI/EMC requirements for harsh environment applications are often more severe than these commercial standards. With the exception of the board-mounted R23 micro module, R-Series amplifiers are designed with features to enhance their EMI performance, especially regarding susceptibility to external electromagnetic fields.

The plastic covers on the R-Series amplifiers are coated with a specialty silver/copper coating. This coating, in conjunction with EMI gasketing at the cover-chassis interface and the aluminum amplifier chassis, serve to form an electrically conductive shell around the amplifier circuit boards. This conductive shell acts as a Faraday shield that greatly reduces the strengths of external electromagnetic fields that could otherwise cause board-mounted electronics to malfunction.

1.2.4: Structural Enhancements

Copley amplifiers contain some tall, board-mounted components that are well suited for commercial shock and vibration environments, but require additional mechanical support to endure the high shock and vibration encountered in harsh environment applications.

In the R-Series, these components are secured to one another and to adjacent structures to provide the necessary support to endure high shock and vibration levels.

1.2.5: RS-422 and RS-485 Serial Communications

R-Series amplifier configuration and control can be performed over the serial port. However, the single-ended performance of RS-232 may not be robust enough for noisy environments. Although RS-232 is the standard protocol on the R-Series amplifiers, RS-422 or RS-485 are available as options. The differential nature of RS-422 and RS-485 provides for higher immunity and thus more reliable communications in noisy environments.

CHAPTER 2: CONFORMANCE

This chapter provides a detailed overview of standards conformance, including an in-depth discussion of the rigorous R-Series qualification test protocol. It also provides application guidance, including suggestions regarding which R-Series models are most appropriate for certain MIL electric power standards.

Contents include:

2.1: In-house Qualification Testing

The R-Series design verification process starts with a pre-production build of approximately 20 units of each model. Each of these pre-production units is tested in-house at the extremes of operating temperature. This qualification testing takes place before any formal third-party environmental testing.

The R-Series in-house extreme temperature testing uses two connected pieces of test equipment. The first is a Labview-based, automated test station. This is a Copley designed, universal test stand identical to those used on Copley's production test floor. The second is a temperature forcing system, a portable environmental chamber that can heat or cool the amplifier under test while the amplifier is connected to and under the full control of the automated test station. In this system, only the temperature local to the amplifier under test is controlled by the temperature forcing system. The temperature of all support equipment, including the universal test stand, remains at room ambient.

In production, the test stands run each Copley Controls amplifier unit through a sequence of tests that measure and record a variety of amplifier parameters including bandwidth, offset current, peak current, and continuous current. Because the amplifier test stand is under computer control, a complete test sequence (consisting of 50 or more individual tests) can be repeated very efficiently to exacting specifications. Using both production and customized test sequences, the universal test stand with the temperature forcing system makes for a very powerful and accurate design verification tool.

A clean "all PASS" production test sequence at -40° C is required on each R-Series pre-production build unit before proceeding with any third-party environmental testing.

2.2: Environmental Specifications and Conformance

2.2.1: R Series Environmental Specifications

Environmental Condition		Endurance Range	MIL-STD 810F Method	Other Standards
Ambient Temperature	Non-Operating	-50ºC to 85ºC	501.4, 502.4	
	Operating	-40ºC to 70ºC		
Thermal Shock	Operating	-40ºC to 70ºC in 1 minute	503.4	
Relative Humidity	Non-Operating	95% non-condensing at 60ºC	507.4	
	Operating	95% non-condensing at 60ºC		
Vibration	Operating	5 Hz to 500 Hz, up to 3.85 g_{rms}	514.5 (Figure 514.5C-2)	IEC 60068-2-6
Altitude	Non-Operating	-400 m to 12,200 m	500.4	
	Operating	-400 m to 5,000 m		
Shock	Crash Safety	75 *g* peak acceleration	516.5	IEC 60068-2-27
	Operating	40 *g* peak acceleration		

2.2.2: R Series Baseline Environmental Standards Conformance

Certain environmental endurance standards are highly relevant to extreme servo amplifier applications. These include selected sections of MIL-STD 810F and IEC 60068. All R-Series servo amplifiers have been qualified to the following baseline environmental standards. Conformance to these standards has been verified through product testing at a certified, independent environmental test lab.

Standard	Description
MIL-STD 810F, 501.4	High Temperature
MIL-STD 810F, 502.4	Low Temperature
MIL-STD 810F, 503.4	Temperature Shock
MIL-STD 810F, 507.4	Humidity
MIL-STD 810F, 514.5 (Figure 514.5C-2)	Vibration
IEC 60068-2-6	
MIL-STD 810F, 520.2	Temperature, Humidity, Vibration, and Altitude
MIL-STD 810F, 516.5	Shock
IEC 60068-2-27	

The baseline standards are expected to cover the requirements in the vast majority of applications. However, given the wide variety of potential applications for R-Series servo amplifiers, it is not practical to anticipate and test to all environmental standards that customers may require. In the event that conformance to other standards is required, please contact Copley Controls.

Test data for specific R-Series models is available upon request.

2.2.3: Environmental Standards Compliance: Third-Party Testing Overview

After in-house qualification testing and standard production floor testing, Copley R-Series amplifiers are subject to rigorous enviornmental testing by a certified independent laboratory. The third-party tests are performed on samples of each R-Series amplifier model in adherence to the appropriate MIL-STD procedures as described in this section.

2.2.4: Extreme Temperature Conditions: Third-Party Test

High Temperature (Method 501.4)

Method 501.4 specifies the procedures for verifying the product for both storage at high temperature (Procedure I) and operation at high temperature (Procedure II). The test method allows for either a constant temperature test or a cyclic temperature test. The cyclic testing is intended for applications where the item temperature is highly dependent on the time of day (outdoors). The constant temperature testing is intended for applications where the item temperature is mainly determined by local operating conditions (in an enclosure). Since servo amplifiers are normally mounted within a vehicle or other enclosure, the constant temperature test approach was selected for the R-Series amplifier testing.

Procedure I requires that the item under test be in a non-operating state and “soaked” at the storage temperature extreme until the temperature of the item has remained stable at the extreme for a minimum of 2 hours. Procedure II is similar to Procedure I except that the item under test is run in a normal operating condition for the duration of the test.

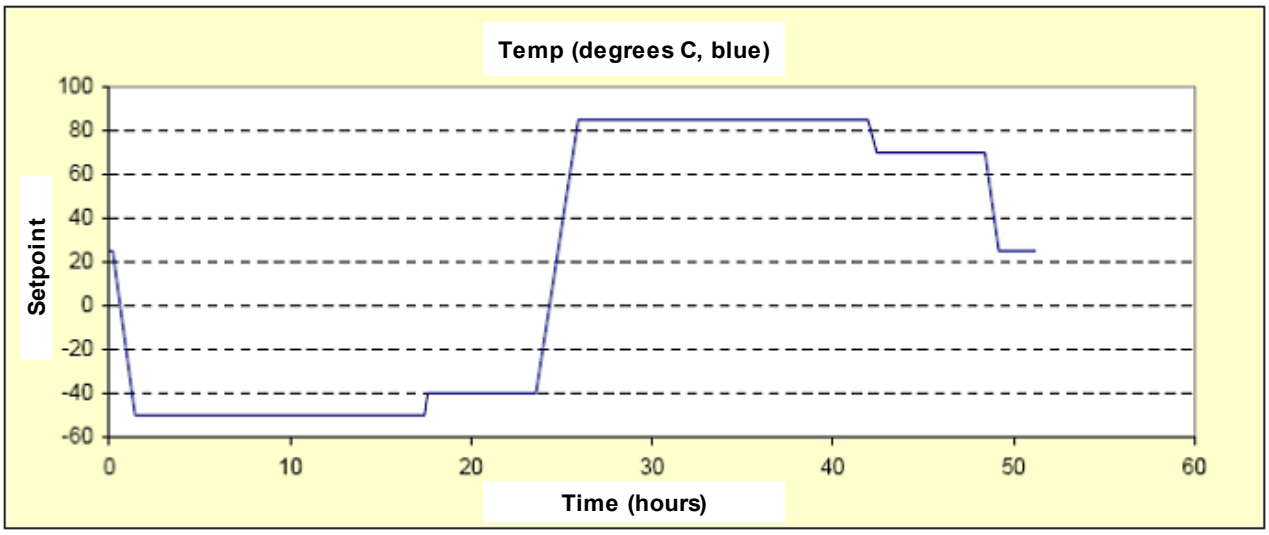
Low Temperature (Method 502.4)

Method 502.4 specifies the procedures for verifying the product for storage at low temperature (Procedure I), operation at low temperature (Procedure II) and manipulation at low temperature (Procedure III). Procedure III is not applicable to servo amplifiers; it is applicable only to equipment that is set-up/disassembled by personnel wearing cold-weather clothing.

Procedure I requires that the item under test be in a non-operating state and “soaked” at the storage temperature extreme until the temperature of the item has remained stable at the extreme for a duration as specified by the manufacturer’s test plan. Procedure II is similar to Procedure I except that the item under test is run in a normal operating condition for the duration of the test.

Extreme Temperature Independent Test Description

The following graph shows an actual temperature vs. time profile from the test lab report for the Xenus R10-230-36-HS. Samples of each R-Series model undergo the same test.



As described below, this profile covers all four of the required time/temperature test conditions (low temperature storage, low temperature operation, high temperature storage, and high temperature operation):

Low Temperature Storage: The test begins with the amplifier in a non-operating state at 25° C. Within two hours, the temperature is lowered to -50° C, where it soaks for approximately 17 hours.

Low Temperature Operation: At hour 18, the temperature is raised to -40° C and power is applied to the amplifier. The amplifier is enabled and used to drive a motor at -40° C for approximately 6 hours. Power is then removed from the amplifier and the temperature is raised to 85° C.

High Temperature Storage: With the amplifier still un-powered, the temperature is stabilized at 85° C for approximately 17 hours.

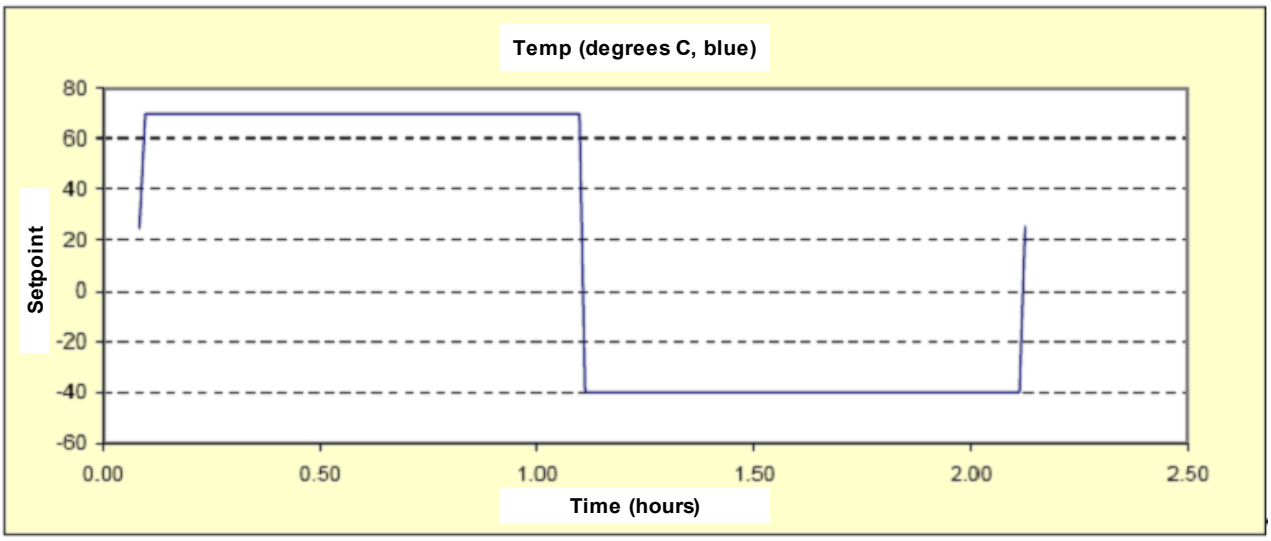
High Temperature Operation: At approximately hour 44 the chamber setpoint temperature is reduced to 70° C. Once the amplifier temperature stabilizes, power is restored and the amplifier is enabled and used to continuously drive a motor for approximately six hours. The temperature is lowered to base temperature (25° C) over a period of approximately an hour, and operated for another two hours at 25° C, thus completing the test.

2.2.5: Temperature Shock (Method 503.4): Third-Party Test

Temperature shock testing determines whether a product can withstand sudden changes of ambient temperature without experiencing physical damage or deterioration in performance. This type of testing simulates the rapid temperature changes that can occur during shipping and handling. One example of temperature shock described in MIL-STD-810F is the temperature change experienced by equipment when it is dropped from an aircraft at high altitude/low temperature. Since equipment is typically un-powered during shipping and handling, temperature shock testing is performed with the product in a non-operational state.

Method 503.4 contains two different procedures for performing temperature shock testing. Procedure I is referred to as “steady-state” since it calls for the ambient temperature to be alternated between two temperature extremes. Procedure II is referred to as “cyclic” and calls for a careful simulation of the real environment a given product is expected to experience.

Procedure I testing is considered to be the most severe. Copley’s R-Series products are tested using Procedure I. All R-Series amplifiers are tested against a time/temperature profile like the actual test sample depicted in the following chart.



This profile can be described by the following sequence of phases:

Initialization: The Procedure I testing is initiated by raising the product temperature to 70° C.

High temperature soak: The amplifier is soaked at 70° C for approximately an hour.

Rapid drop to low temperature: Once the product temperature is stabilized at 70° C (fully soaked), the temperature is rapidly reduced to the low temperature extreme (-40° C). As per Method 503.4 Procedure I, the complete 70° C to -40° C temperature excursion takes place in one minute or less.

Low temperature soak: The amplifier is then soaked at -40° C for approximately an hour.

Rapid rise to high temperature: Once the product temperature is stabilized at -40° C (fully soaked), the temperature is rapidly increased to the high temperature extreme (70° C). As per Method 503.4 Procedure I, the complete temperature excursion takes place in one minute or less.

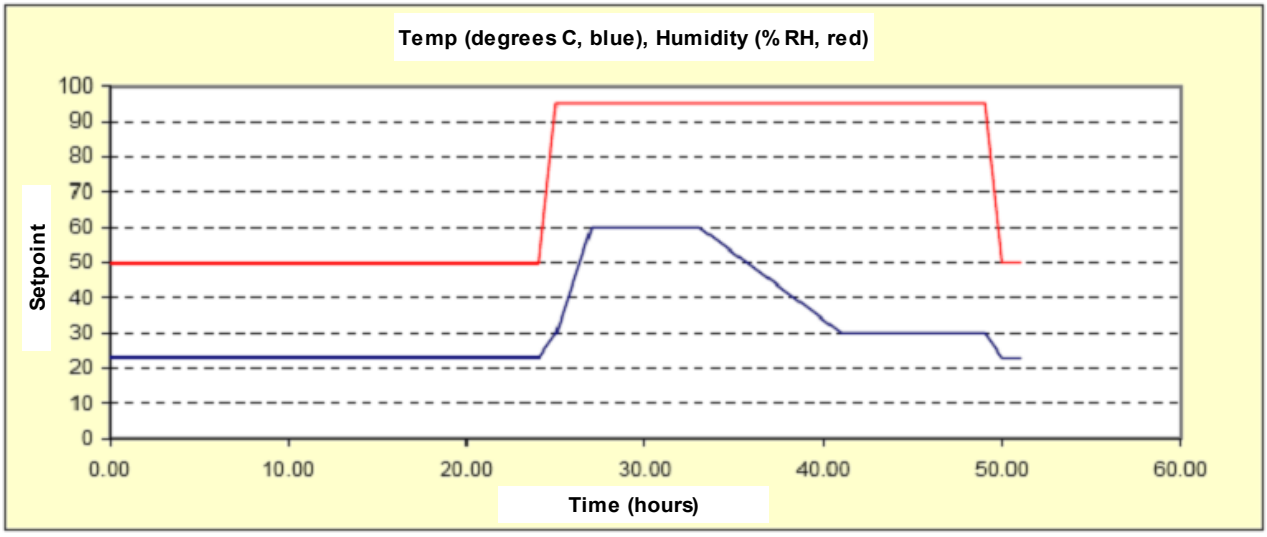
This high-low-high temperature cycle is repeated nine times to expose the amplifier to a total of ten temperature shock cycles.

2.2.6: Humid Environment (Method 507.4): Third-Party Test

The purpose of humidity testing is to determine the resistance of the product to the effects of a warm, humid operating environment. According to MIL-STD-810F, Method 507.4 does not "attempt to duplicate the complex temperature/humidity environment." Rather, it provides a "generally stressful situation that is intended to reveal potential problem areas" of the equipment being tested. The standard calls for a minimum of five 48-hour temperature/humidity cycles. This requirement is based on data indicating that testing lasting 10 days or more is adequate to reveal potential problems in the equipment under test.

The standard also specifies extreme conditions of 95% relative humidity (RH) and 60° C. Although this combination of conditions does not occur in nature, "these levels of temperature and relative humidity have historically provided an indication of potential problem areas" in the equipment being tested.

The following chart shows the time/temperature/humidity profile that the Copley R-Series amplifiers are subjected to during the humid environment testing. The amplifier under test is powered and controlling a motor for the duration of the test. This profile shows the 24-hour initialization followed by the first of nine 27-hour temperature/humidity cycles. Note that the amplifier under test is subjected to the extreme 60° C/95% RH operating point for approximately eight hours out of every 27-hour cycle.



2.2.7: Altitude (Methods 500.4 and 520.2): Third-Party Test

Altitude testing on the Copley R-Series amplifiers is performed in accordance with Method 500.4 of MIL-STD-810F, but also with some guidance from Method 520.2. The primary concerns of altitude on motor drive amplifiers and similar equipment are overheating due to reduced heat transfer and malfunction due to arcing or corona.

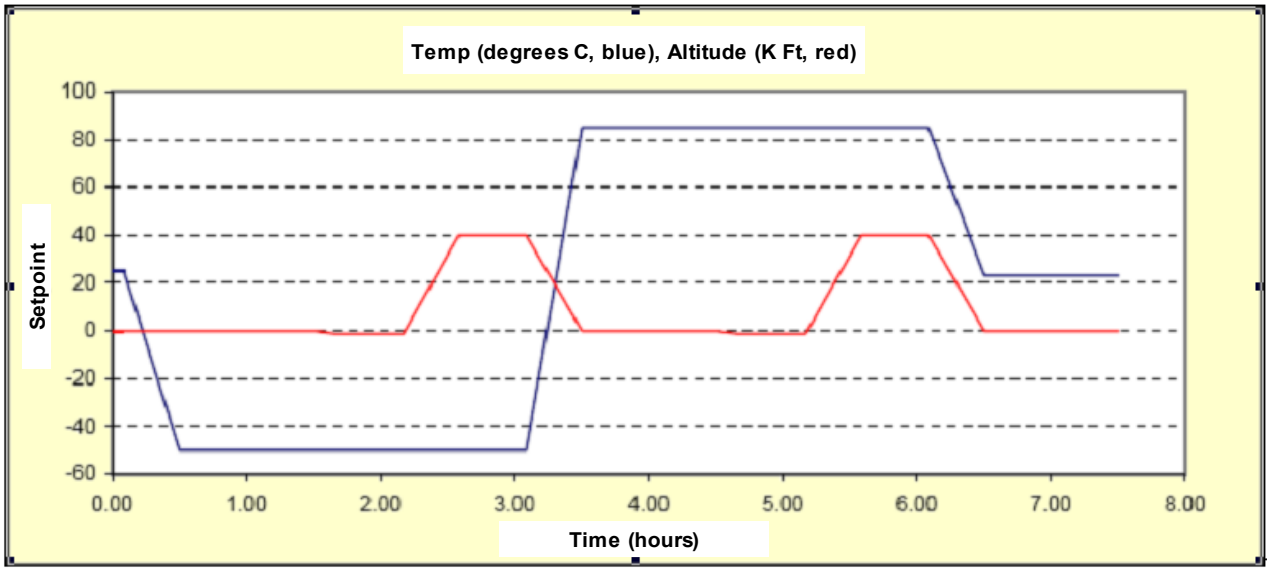
The purpose of the altitude testing is to verify that the Copley R-Series amplifiers can withstand and/or operate in low pressure (high altitude) environments without overheating or malfunction due to arcing.

Method 500.4 deals strictly with altitude whereas Method 520.2 considers the combined effects of temperature, humidity, vibration, and altitude. For the Copley R-Series testing, temperature is varied along with altitude (pressure) since changes in temperature almost always coincide with changes in altitude.

Method 500.4 Procedure I simulates air transport/storage conditions and is a non-operating test. Procedure II is an operational test and is limited to altitudes encountered in typical applications for Copley R-Series amplifiers.

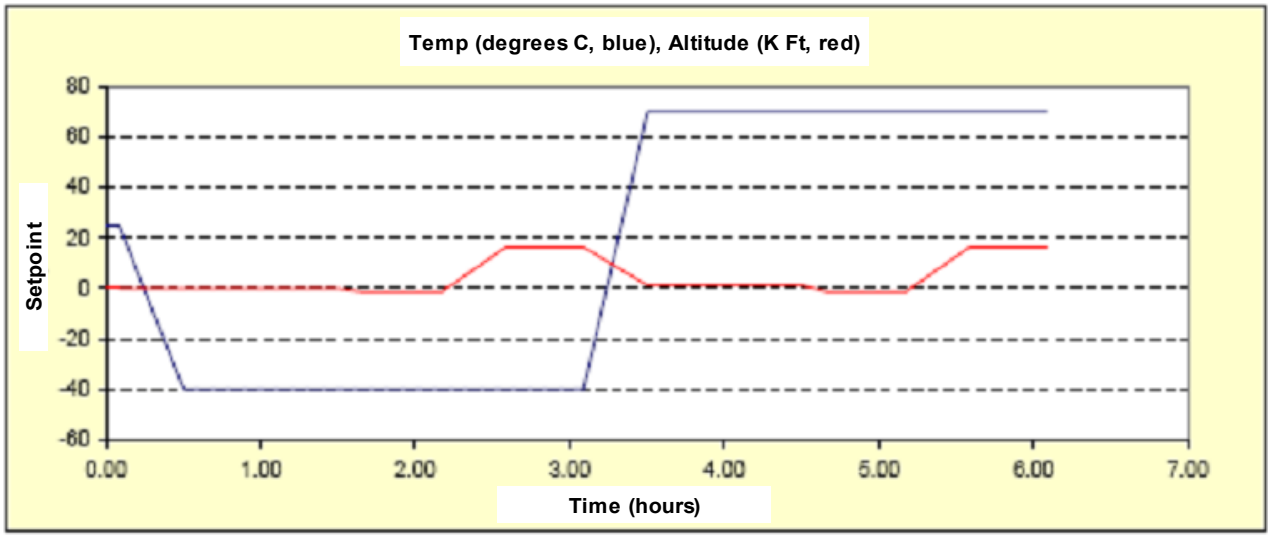
Storage (Non-Operating) Altitude Test

The following graph shows the time/altitude/temperature profile used for the non-operating storage test. Note that the altitude is varied between -400 m (-1300 ft) and 12,200 m (40,000 ft) and that the temperature is varied over the full rated storage temperature range (-50° C to +85° C). Note too that the altitude and temperature are cycled such that the altitude extremes are reached during both the high and low temperature excursions.



Operational Altitude Test

The next graph shows the time/altitude/temperature profile for the operational altitude test (Procedure II). The altitude is varied between -400 m (-1300ft) and 5000 m (16,400 ft) and the temperature is cycled over the full rated operating temperature range (-40° C to 70° C). As with the storage test, altitude and temperature are varied so that the altitude extremes are reached during both the high and low temperature excursions.



2.2.8: Random Vibration Testing (Figure 514.5C-2): Third-Party Test

According to MIL-STD-810F, vibration testing is intended to verify that the device under test will function in and withstand the vibration exposures of a life cycle. The section in MIL-STD-810F concerning vibration testing is extensive, in part because it addresses a wide variety of end use applications.

For the purposes of baseline product testing, Copley R-Series amplifiers are vibration-tested to the random vibration profile given in MIL-STD-810F Fig. 514.5C-2. This profile applies to equipment installed in ground vehicles. Figure 514.5C-2 is shown here for reference:

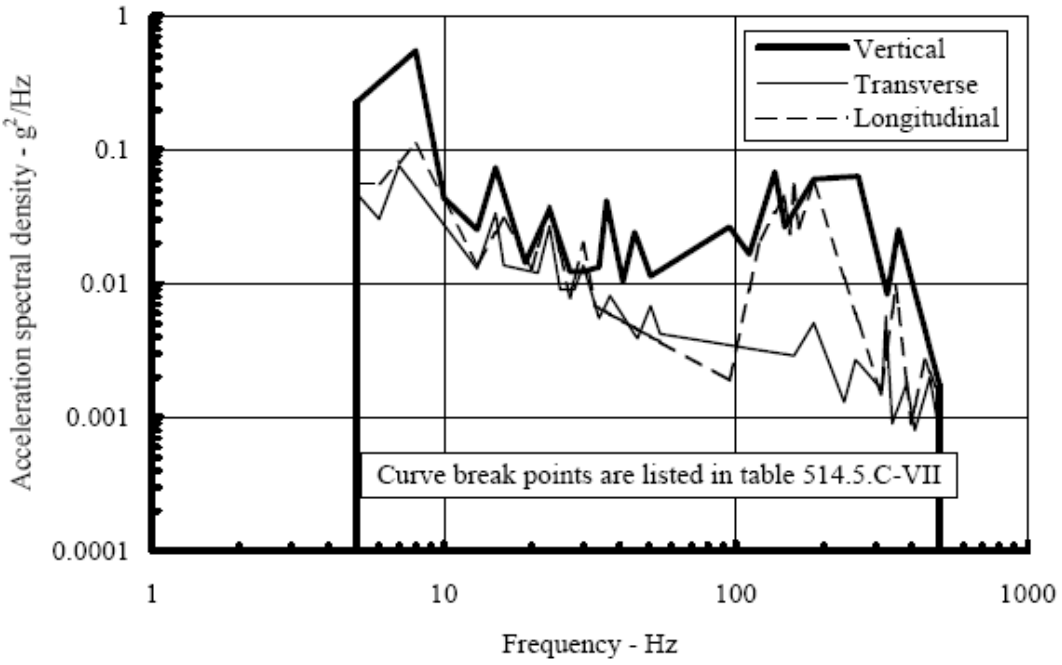


FIGURE 514.5C-2. Composite two-wheeled trailer vibration exposure.

Random vibration, as opposed to sinusoidal vibration, is used in ground-based vehicle testing because the vibrations induced by the road/terrain are not regular or periodic. For this testing the R-Series amplifiers are mounted on a vibration table and subjected to the reference random vibration profile for one hour on each axis. The amplifiers are fully operational during the test and are continuously monitored to ensure they operate normally and without any faults for the duration of the test.

Note that the amplifier under test is exposed to frequencies in the range from 5 Hz up to 500 Hz. The net RMS acceleration defined by the vibration exposure curve (514.5C-2) is different for each axis of vibration. For the complete 5 Hz to 500 Hz range, the net RMS acceleration is 3.85 g*rms*, 1.28 g*rms* and 2.40 g*rms* for the vertical, transverse and longitudinal axes respectively. At the completion of testing, all of the test amplifiers are disassembled and inspected to verify that no damage or excessive wear has occurred.

2.2.9: Shock (Method 516.5 and IEC 60068-2-27): Third-Party Test

According to MIL-STD-810F shock testing is performed to “provide a degree of confidence that materiel can physically and functionally withstand the relatively infrequent, non-repetitive shocks encountered in handling, transportation and service environments.” Method 516.5 covers all aspects of mechanical shock testing. Copley R-Series amplifiers are shock tested using Procedures I and V of Method 516.5.

Procedure I addresses functional shock. It covers mechanical shock events that can occur during normal operation. The amplifier is expected to function normally before, during, and after these shock events.

Procedure V is concerned with ensuring that materiel mounted inside of a vehicle does not break loose from its mounts as a result of the high shock levels encountered during a vehicle crash. The equipment under test does not have to functionally survive the crash event, but it must remain safely mounted as originally installed.

Table 516.5-1 and Fig. 516.5-8 of method 516.5 specify both the functional and crash safety shock levels for ground equipment.

For Procedure I functional shock testing, the R-Series amplifiers are mounted to a vibration table and subjected to mechanical shock events affecting all three axes. During functional shock testing, the amplifiers are fully functional (driving a motor) and are monitored continuously to ensure proper operation throughout the test. Following functional shock testing, the amplifiers are subjected to a full functional test and are then disassembled and inspected to ensure that no damage or excessive wear has occurred.

Procedure V crash safety shock testing is performed only after successful Procedure I functional shock testing. The crash shock test method is the same as for functional shock except that the acceleration levels are much higher (75 g vs. 40 g).

The following tables, from an Xenus R10 test report, show the crash shock levels along with a record of the number and direction of shock pulses applied. Samples of each R-Series model undergo the same test.

Functional Shock		Crash Safety Shock	
Frequency (Hz)	**G’s**	**Frequency (Hz)**	**G’s**
10	9	10	9
45	40	80	75
2000	40	2000	75
# of Pulses Per Direction	3	**# of Pulses Per Direction**	3
# of Axes	3	**# of Axes**	3
Total # of Pulses	18	**Total # of Pulses**	12
Control Accel Location	1 on fixture	**Control Accel Location**	1 on fixture
Response Accel 1 Location	N/A	**Response Accel 1 Location**	N/A
Response Accel 2 Location	N/A	**Response Accel 2 Location**	N/A
Response Accel 3 Location	N/A	**Response Accel 3 Location**	N/A

The objective of the Procedure V crash safety shock testing is to ensure that the equipment under test does not break loose from its mounting and thus create a safety hazard. The equipment does not have to function following the test. Following the crash shock testing, the amplifiers are disassembled and inspected for damage and wear.

It is worth noting that most of the Copley R-Series amplifiers survived the Procedure V crash shock testing without damage or loss of function following the test.

2.3: Safety

Copley's R-Series amplifiers are reviewed and tested for conformance to the appropriate safety standards for the purpose of CE marking and UL recognition. EN 61010-1 is an international standard that specifies the "safety requirements for electrical equipment for measurement, control and laboratory use." UL508C is a UL standard for safety that specifically addresses power conversion equipment. Conformance to both of these standards is verified through a constructional review and laboratory testing performed and/or witnessed by UL engineers. Key aspects of the constructional review and testing are as follows:

- Verification that critical components have the appropriate agency approvals and/or are constructed in such a way to prevent electric shock and fire hazards.
- Verification that the spacing (creepage and clearance) between high voltage and low voltage circuits meets the requirements given in the standards
- Temperature Test: The purpose of this test is to verify that the temperature of PCB mounted components does not exceed the printed circuit board rating under worst case amplifier loading conditions. For the R-Series amplifiers, this test is conducted at the 70° C maximum rated operating temperature.
- Abnormal Test: The purpose of this test is to verify that electric shock and fire hazards do not result from the failure of critical components. Failures are intentionally induced in one critical component at a time. Components are either shorted or open circuited – whichever failure mode is most likely to result in a hazard.
- Hi-pot Testing: This testing typically applies only to AC powered amplifier models (like the R10 and R11). Following the temperature and abnormal testing, a hi-pot test voltage is applied between AC line connected circuits and low voltage circuits (including the chassis) to verify the integrity of electrical safety isolation.
- Overload and Short Circuit Testing: This testing verifies that the amplifier's overload and short circuit functions operate effectively. Specifically, the test engineer induces an overload and/or short circuit condition at the amplifier output and confirms that an electric shock or fire hazard does not result.

In addition to the aforementioned safety standards, some R-Series customers have inquired about conformance to IEC 60079-15. This standard addresses the construction, test and marking of type "n" electrical apparatus for explosive gas atmospheres. Using design guidance from engineers at a certified, independent laboratory and safety consulting firm, most of the Copley R-Series amplifiers have been designed with the intent to meet IEC 60079-15. A key R-Series design feature relevant to IEC 60079-15 is the use of conformal coated circuit board assemblies. IEC 60079-15 is tailored toward the prevention of sparks and arcing in electrical apparatus. Conformal coating as specified in section 6.7.3 of the standard provides a protective insulating layer and thus reduces the chance of sparks and arcs occurring on a given circuit board.

Formal confirmation and declaration of conformance to IEC 60079-15 for R-Series amplifiers (other than the R10) would require testing by an independent Notified Body organization. Please contact Copley Controls in the event that a formal declaration of conformance is required. Note that the Xenus R10 amplifiers do not meet the IEC 60079-15 requirements.

2.4: Electromagnetic Compatibility (EMC)

The R-Series amplifiers are tested by a certified third-party EMC test house for conformance to international standards concerning EMC for both emissions and immunity. Standard EN 55011:1998 addresses the limits for radio frequency interference for industrial, scientific and medical equipment. Standard EN 61000-6-1:2001 covers the immunity requirements for electrical equipment.

The R-Series amplifiers (R23 excluded) have been designed with features to enhance their EMI performance, especially with regards to electromagnetic field susceptibility.

The plastic covers on the R-Series amplifiers are coated with a specialty silver/copper coating. This coating, in conjunction with EMI gasketing at the cover/chassis interface and the aluminum amplifier chassis, serves to form an electrically conductive shell around the amplifier circuit boards. This conductive shell acts as a faraday shield to greatly reduce the strength of external electromagnetic fields that could otherwise cause board-mounted electronics to malfunction.

In general, the R-Series amplifiers do not meet all of the detailed requirements of MIL-STD-461E “out of the box.” Although the enhanced EMI features designed into the R-Series provide a measurable benefit, several of the MIL-STD-461E detailed requirements are much more stringent that the commercial standards. In these applications, the R-Series amplifier would require additional enclosure, components, and/or shielding to achieve conformance to MIL-STD-461E.

MIL-STD-461E conformance is very application-specific. Not all of the standard’s detailed specifications are required in every application. Contact Copley for assistance with using R-Series amplifiers in applications requiring conformance to MIL-STD-461E.

2.5: Application Support

2.5.1: Copley Application Design Support

The importance of supplier technical support in ensuring that projects are completed on time and on budget cannot be overstated. This is especially true for rugged applications. Copley has over 25 years experience in the manufacture of innovative and reliable servos and power systems. We have a very responsive R&D and applications team. These motion control and power experts stand ready to support R-Series deployments.

The R-Series technical data sheets and design guides provide the level of detail needed to design-in the amplifier. The technical data sheets contain detailed information on thermal management and mounting to ensure proper operation at temperature extremes and in high shock/vibration environments.

2.5.2: Application-Specific Electrical Standards

There is a wide variety of application-specific electrical standards relating to the types of military and harsh environment equipment for which R-Series amplifiers are intended. The R-Series family of amplifiers covers a range of input voltage levels and types (AC or DC). The following table is a design guide that lists a number of these application-specific electrical standards and identifies which R-Series amplifiers are most applicable to the given standard.

MIL-STD	Description	Primary Voltage	Suggested R-Series Amplifiers
MIL-STD-1275D	Characteristics of 28 Volt DC Electrical Systems in Military Vehicles	28Vdc	R20, R21, R22, R23
MIL-STD-704F	Aircraft Electric Power Characteristics	28Vdc	R20, R21, R2, R23
		270Vdc	R10, R11
		115/200VAC, 400Hz	R10, R11
		115VAC, 60Hz	R10, R11
MIL-STD-1399	Section 300A, Electric Power, Alternating Current	115VAC, 60Hz	R10, R11
MIL-STD-1399	Section 390, Electric Power, Direct Current for Submarines	155Vdc	R10, R11, R20-180, R22-180

The preceding table is a set of application guidelines based on a careful review of R-Series electrical designs against the standards requirements. If formal testing to these application-specific electrical standards is needed, contact Copley Controls.

MIL-STD-1275D

MIL-STD-1275D “covers the limits of steady state and transient voltage characteristics” of the 28 Vdc supply found in military vehicles. Based on careful review of R-Series electrical designs against the 1275D requirements, Copley’s DC powered R-Series amplifiers are generally suitable for systems requiring MIL-STD-1275D conformance.

There are some aspects of this standard that may require the addition of system level components (external to the amplifier) in order to achieve conformance. They include starting disturbance and ESD protection.

Starting Disturbance: The first aspect of the MIL-STD-1275D standards that may require the addition of system level components is the set of starting disturbance characteristics described in Fig. 4 of the standard. The starting disturbances are undervoltage variations caused by engine starting and cranking. During the “initial engagement surge” the DC voltage drops down as low as 6 V and then recovers exponentially to 16 V over a one-second time period. Depending on how the R-Series amplifier is used in the system, the amplifier will likely continue to operate through this initial one-second time period. However, the amplifier’s ability to maintain control of current/velocity/position will be compromised because of the reduced DC supply voltage.

Once the voltage has recovered to 16 V, it can remain at that level for up to 30 seconds (engine cranking). With the exception of the model R23 amplifiers, the DC powered R-Series amplifiers (R20, R21 and R22) are specified for steady state operation down to 20 V (the R23 amplifiers are specified down to 14 V). At levels below 20 V, the standard R20, R21 and R22 amplifiers go into an undervoltage fault condition. If operation below 20 V is required, please contact Copley Controls.

ESD Protection: The second aspect of the MIL-STD-1275D standards that may require the addition of system level components is the ESD (electrostatic discharge) requirement. The standard specifies ESD conformance to the SAE J1113-13 automotive standard. All of the R-Series amplifier designs have been qualified and tested to the ESD requirements of EN 61000-4-2, but the SAE standard is more severe. Depending on the system design, surge suppression components on the amplifier signal level inputs and outputs may be required to meet the SAE ESD levels.

MIL-STD-704F

The aircraft electric power standard 704F addresses the five different power supply types found in aircraft applications (three AC power supply types and two DC). The most common AC type is 115/200 Vac at 400Hz. The other two AC types are variable frequency (360 Hz to 800 Hz) 115/200 Vac and 115 Vac single phase, 60 Hz, which is intended for use only in support of COTS equipment. These AC supplies are generally suitable for the R10 and R11 Xenus amplifiers under “normal” operating conditions. However, there are two potential issues relating to these AC supply voltages as defined in MIL-STD-704F.

The first issue is power factor: Paragraph 5.4.3 of the standard specifies that “power factor of AC equipment greater than 500 VA shall be between 0.85 lagging and unity when operating at 50 percent or more of its rated load current in steady state condition.” The power factor for the R10 and R11 models is typically about 0.70 lagging. These amplifiers convert the incoming AC to DC with a diode rectifier and capacitor bank, which accounts for the relatively low power factor. Depending on loading, the R10 and R11 amplifiers may or may not meet the power factor requirement as specified in the standard.

The second issue is leakage current. Leakage current is the current that flows from the incoming AC line(s) to the chassis. The most common path for leakage current is through the EMI suppression capacitors inside the equipment. These are connected between the AC line inputs and chassis ground. The amount of leakage current depends on the AC input voltage and frequency as well as the “wye” connected EMI capacitance. Some systems specify an upper limit on the amount of leakage current for safety reasons. The user should compare the leakage current requirements for each application with leakage current specifications published in the amplifier data sheets.

The two DC supply types specified in the MIL-STD-704F requirements are 28 Vdc and 270 Vdc. The 28 Vdc supply described in the standard is suitable for the powering the DC powered R-series amplifiers (R20 through R23). However, none of the DC R-series amplifiers are rated for operation from 270 Vdc. The maximum input voltage rating for the DC amplifier family is 180 Vdc. Therefore, the only R-series drives capable of operating from 270 Vdc are the R10 and R11. Although the R10 and R11 are normally considered for operation from AC input power, they can be run from DC as well.

MIL-STD-704F defines a number of different operating conditions under which the power supply characteristics differ from “normal.” Within the standard, the aircraft electric power characteristics are specified for “Abnormal,” “Transfer,” “Emergency,” and “Starting” operating conditions. Some of the transient voltage levels that occur in these non-normal operating conditions are outside of the R-series ampliifier ratings. Depending on the magnitude and duration of these transients, the R-series amplifiers may shut down due to overvoltage/undervoltage faults or may power down completely. In sections 4.2.2.2 through 4.2.2.5, MIL-STD-704F requires that the “utilization equipment shall provide the level of performance specified in its detail specification” in these non-normal operating conditions. Thus, the suitabilty of a given R-series amplifier for an aircraft electric power application depends on the requirements of the particular application and is not solely determined by MIL-STD-704F.

MIL-STD-1399 (Navy) Section 300A, Electric Power, Alternating Current

Section 300A of MIL-STD-1399 specifies several different types of AC electric power, but the standard indicates a preference that most shipboard equipment operate from Type I 60 Hz power. Type I power is available at both 440 Vac and 115 Vac levels, single-phase or three-phase, and is ungrounded. Type I, 115 Vac power is suitable for operating the Copley R10 and R11 R-series drives.

Unlike some of the other standards, MIL-STD-1399 Section 300A requires detailed testing to verify conformance. Tests include the Voltage Spike Test (paragraph 5.3.3), the Emergency Condition Test (paragraph 5.3.4), and the Current Waveform Test (paragraph 5.3.7). Due to the number and extent of the required tests, full compliance testing to this standard typically takes 4-5 days of test time at certified test facility. Although the R10 and R11 drives have not been tested to this standard, we have reviewed the drive designs against the requirements.

The test methods and levels required in the Voltage Spike Test are quite similar to those in EN 61000-6-1:2001. The R10 and R11 have been tested to EM 61000-6-1:2001 for the purposes of CE marking and thus they would be expected to pass the Voltage Spike Test. Other MIL-STD-1399 Section 300A requirements and tests impose restrictions on power factor, in-rush current, and current harmonics.

As mentioned in the MIL-STD-704F discussion, the R10 and R11 amplifiers convert the incoming AC to DC with a diode rectifier and capacitor bank. The resulting power factor is typically about 0.7 lagging but depends on amplifier loading and whether the amplifier is powered from 3-phase or single-phase. The MIL-STD-1399, low end requirement on power factor is 0.8 lagging, so this could be an issue in some applications.The drives employ in-rush current limiting and as a result should meet the requirements specified in Fig. 14 of the standard. The diode rectifier and PWM action of the R10 and R11 also contribute to the harmonic content of the current drawn from the AC supply. Compliance to the current harmonic requirements is difficult to determine analytically, but some applications may require conditioning circuits between the AC supply and the amplifier to meet the specifications given in the standard.

MIL-STD-1399 (Navy) Section 390, Electric Power, Direct Current for Submarines

The 1399 standard specifically addresses the requirements for equipment operating from a 155 Vdc supply on submarines. This standard imposes more requirements than its AC counterpart (Section 300A) in that it incorporates many aspects of MIL-STD-461E for EMC and specifically requires conformance testing, a systems analysis and equipment schematics. Paragraph 6.1 makes note that the standard “does not prohibit the use of 60Hz power” as specified in Section 300A. This suggests that the use of Type I power is preferred over Section 390 DC power as well as the other power types specified in Section 300A of MIL-STD-1399.

The model R10 and R11 R-series amplifiers as well as the 180V rated R20 and R22 models are suitable for use with MIL-STD-1399 Section 390 power. There are several specification areas that should be considered when deploying R-series amplifiers in a Section 390 system. The first area consists of the EMC and ripple current requirements listed in paragraphs 5.3.1 and 5.3.2 . These paragraphs impose aspects of MIL-STD-461E and as such additional components, enclosures, and shields may be necessary to meet the requirements. Refer to the discussion on MIL-STD-461E in Electromagnetic Compatibility (EMC) (p. 23).

Paragraph 5.3.8 specifies that “user equipment 155-Vdc input terminals shall be isolated from all user equipment loads such as power conversion equipment outputs.” To maximize efficiency and minimize size and cost, the R-series drives do not provide electrical isolation between the primary power inputs and the motor power outputs. This motor drive architecture is widely accepted in the industry. We believe that paragraph 5.3.8 is intended for DC/DC power supplies and is not applicable to motor drives.

Paragraph 5.3.9.1 specifies that “user equipment requiring protection from polarity reversal shall be internally protected from improper connection at any point in the system.” The primary power connections for the R10 and R11 amplifiers do not have a polarity requirement, because these models can be powered from AC as well as DC. The R20-180 and R22-180 models accept DC power only and they do not have internal reverse polarity protection. Reverse polarity protection would have to be employed external to the amplifier, but internal to the “user equipment” of which the drive is a part.

2.6: Summary

Although the range of standards covered in the R-Series qualification testing is quite extensive, Copley Controls recognizes that some applications may require qualification testing to additional standards. Because of this we expect to add to the list of standards over time as application-specific needs are addressed. If conformance to other standards is required, please contact Copley Controls for the latest information or to inquire about working with us to qualify the R-Series to other standards.

Ruggedized Drives Standards Guide

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