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USACE / NAVFAC / AFCEC **UFGS-26 35 43 (August 2021)**

Preparing Activity: NAVFAC **Superseding**
UFGS-26 35 43 (May 2011)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2024
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400-HERTZ (HZ) SOLID STATE FREQUENCY CONVERTER

08/21

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SECTION 26 35 43

400-HERTZ (HZ) SOLID STATE FREQUENCY CONVERTER
08/21

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NOTE: This guide specification covers the requirements for the procurement, installation, and testing of 400 Hz solid state frequency converters.

1) Combination converters (having both "400 Hz and 28 VDC" power outputs) are no longer permitted on Navy projects. When a combination converter is required for a specific Army project, edit the title of the specification to "COMBINATION 400 HERTZ AND 28 VDC SOLID STATE CONVERTER", and select the appropriate bracketed options throughout the remainder of the specification.

2) Previous versions of this specification referred to equipment sized only in kVA at 0.8 lagging power factor. The specification now has the requirement to use kW instead of kVA as the unit of power measurement for converters here and on the project drawings. This is a significant change in equipment designation, intending to ensure that our equipment meets the full required load range, including full power at unity power factor. It has been made to eliminate the problems that have been occurring with existing equipment in the field, and to accommodate the increasing nonlinear load characteristics of Military equipment. NAVAIR documents, including their Facilities Requirements Documents (FRD)s, are being revised to coordinate with this change to kW. Army documents are in the review process.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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NOTE: These converters are used to supply 400 Hz electrical power to aircraft and ships in shore facility environments. Typical applications include aircraft operating in flight line conditions or in hangars, avionics shops, laboratories, training buildings, flight simulators, and computer rooms.

This specification is not to be used for procurement of power converters installed on board aircraft or ships without specific authorization from Naval Air Warfare Center Aircraft Division (NAWCAD Power and Energy Division (AB43) at (301) 342-4161), and from the Naval Sea Warfare Command (contact the Technical Warrant Officer for the appropriate ship classification).

This specification is not intended for medium-voltage applications.

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NOTE: For Navy projects, incorporate the special SUBMITTAL REVIEW PROCESS paragraph in the SUBMITTALS section. Coordinate with NAVAIR, NAVFAC, and the Activity to see whether the "review and approval", or the "surveillance only" options are required.

1) If "review and approval" (reach-back support) is desired, for a specific NAVFAC project, the technical representative (electrical engineer) editing this document for that project must contact the NAVFAC Atlantic (LANT), Code DC 44 - Electrical Criteria Manager at (757) 322-4327 for consultation during the design stage of the project, prior to including the requirement in the specification.

2) If "surveillance only" is agreed to, it requires the submittal information to be sent to NAVAIR and NAVFAC LANT for review and comment at the same time as the information is being sent to the Designer of Record for Review and Approval. The surveillance mode would give NAVAIR or NAVFAC LANT the opportunity to confirm compliance, without inadvertently holding up the project if the appropriate personnel are not available to do the review in a timely manner.

The Electrical Designer of Record must also insure that the Division 1, Section 01 33 00 SUBMITTAL

PROCEDURES, paragraphs FORWARDING SUBMITTALS REQUIRING GOVERNMENT APPROVAL and SUBMITTALS RESERVED FOR NAVFAC [_____] APPROVAL of the project document are edited to identify the agreed upon special process.
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NOTE: Coordination is required between this section and the project power systems study to determine which of the standardized Arc Flash Warning labels are required on the equipment. These labels (Graphics) are available in metric (SI) and U.S. Customary (IP) system dimensions. Use these files to develop project specific drawings.

File Name	Description
ARCFLASH	Arc Flash Warning Label

NOTE: To download UFGS Forms, Graphics, and Tables, go to: https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-graphics-tables

Go to the specification section number, select the appropriate Electrical .ZIP file(s) and extract the desired details.

Do not include list of details, or details themselves, in project specifications. Insert the appropriate details on drawings and modify optional and blank items.
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NOTE: The following information must be shown on the project drawings:

1. Show location of all equipment including converter, paralleling controls when required, and remote monitoring and control panels.

2. Provide functional block diagram, single line diagrams, power, and control wiring interconnection diagrams, wiring diagrams, conduit entry diagrams, equipment elevations, maintenance envelope, limiting dimensions, and equipment ratings which are not covered in the specifications.

3. Design equipment rooms with working spaces as required by NFPA 70 and manufacturers extra limitations. Provide ventilation for equipment rooms based on 400 Hz and 28 VDC components heat load generated when operating at 100 percent load. Provide 60 Hz convenience receptacles.
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****
NOTE: Ensure that the 400 Hz distribution system is

properly coordinated including the ratings of the power cables, ground cables, circuit breakers, transformers, filters, rectifiers, and control equipment. Provide calculations in Basis of Design per UFC 3-501-01, Electrical Engineering, including voltage drops, which can be very critical in 400 Hz systems. When replacing a motor generator set with a solid state converter ensure that the existing feeders circuit protective devices will operate properly without damage to electrical devices, including the solid state converter.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D709	(2017) Standard Specification for Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE 519	(2022) Standard for Harmonic Control in Electrical Power Systems
IEEE 1159	(2019) Recommended Practice on Monitoring Electric Power Quality
IEEE C2	(2023) National Electrical Safety Code

IEEE C62.41.1	(2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
IEEE C62.41.2	(2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60947-4-1	(2023) Low-voltage Switchgear and Controlgear, Part 4-1: Contactors and Motor Starters - Electromechanical Contactor and Motor Starters

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ST 20	(2014) Dry-Type Transformers for General Applications
NEMA Z535.4	(2023) Product Safety Signs and Labels

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023; ERTA 4 2023; ERTA 5 2023; ERTA 6 2023) National Electrical Code
NFPA 70E	(2024) Standard for Electrical Safety in the Workplace

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE AS5756	(2021; Rev C) Cable, Power, Electrical, Portable
SAE AS5756/6	(2013; Rev A; Stabilized (S) 2013) Cable, 3-Phase Power, Electric, Portable, Multiconductor, 90 Degree C, 600V, Ozone Resistant, Split Phase
SAE AS7974	(2010; Rev A) Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-DTL-32180	(2004) Cable Assembly, Aircraft Electrical Service

MIL-STD-704	(2016; Rev F; Change 1; Notice 3 2021) Aircraft Electric Power Characteristics
MIL-STD-1399-300	(2018) Low Voltage Electric Power, Alternating Current - Part 1

UNDERWRITERS LABORATORIES (UL)

UL 467	(2022) UL Standard for Safety Grounding and Bonding Equipment
UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 506	(2017; Reprint Jan 2022) UL Standard for Safety Specialty Transformers
UL 1012	(2010; Reprint Apr 2016; Rev Mar 2021) UL Standard for Safety Power Units Other than Class 2
UL 1449	(2021; Reprint Dec 2022) UL Standard for Safety Surge Protective Devices

[1.2 RELATED REQUIREMENTS

****
NOTE: Include this optional reference to Section 26 08 00 APPARATUS INSPECTION AND TESTING when it is already being used and referred to for other electrical equipment on the project. Coordinate with optional paragraph in PART 3.

Coordinate converter equipment with Government's cybersecurity requirements and interpretations. Include this optional reference to Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS if the 400 Hz system includes remote control or remote access capability.
****

Section [26 08 00 APPARATUS INSPECTION AND TESTING][and 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS] applies to this section, with the additions and modifications specified herein.

]1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, must be as defined in IEEE 100.

1.4 SUBMITTALS

****
NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals

required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G". Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy and Air Force projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

****

NOTE: Ensure the optional bracketed "28 VDC Aircraft Power Cable Assembly", and "Remote Monitoring and Control Panel" are not included when those items of equipment are not included in the body of the specification.

****

SD-02 Shop Drawings

Converter Drawings; G[, [_____]]

SD-03 Product Data

Converter; G[, [_____]]

Aircraft Power Cable Assembly; G[, [_____]]

[28 VDC Aircraft Power Cable Assembly; G[, [_____]]

][Remote Monitoring and Control Panel; G[, [_____]]

] SD-06 Test Reports

Work Plan; G[, [_____]]

Routine Factory Test Plan; G[, [_____]]

Special Factory Test Plan; G[, [_____]]

Factory Test Schedule; G[, [_____]]

Routine Factory Tests Certification; G[, [_____]]

Special Factory Tests Certification; G[, [_____]]

SD-07 Certificates

Qualifications of Manufacturer; G[, [_____]]

Nationally Recognized Testing Laboratory (NRTL) Listing; G[, [_____]]

SD-09 Manufacturer's Field Reports

Field Test Plan; G[, [_____]]

Field Test Schedule; G[, [_____]]

Field Test Certification; G[, [_____]]

Training Syllabus; G[, [_____]]

SD-10 Operation and Maintenance Data

****
NOTE: Coordinate with options under paragraph OPERATION AND MAINTENANCE MANUALS.
****

Converter O&MM, Data Package 5; G[, [_____]]

Preliminary Converter O&MM, Data Package 5; G[, [_____]]

[Remote Monitoring and Control Panel, Data Package 5; G[, [_____]]

] **********
NOTE: On Navy projects, include at least one of the bracketed options below. The first option is for surveillance only, and the second option is for complete approval where "reach-back support" has already been coordinated with either NAVAIR or NAVFAC LANT per the third introductory Technical Note. Add the appropriate information in Section 01 33 00 SUBMITTAL PROCEDURES to coordinate with the special requirements.
****

[1.4.1 Government Submittal Review

[NAWCAD Air Vehicle Electrical Power Systems Group (AB43), (301) 342-4161 [and Code CI44, NAVFAC LANT, Naval Facilities Engineering Systems Command] will provide surveillance. If they have comments or concerns, they will contact and coordinate resolution of their comments with the appropriate approving agent.

] [(NAWCAD Air Vehicle Electrical Power Systems Group (AB43), (301) 342-4161][Code CI44, NAVFAC LANT, Naval Facilities Engineering Systems Command][_____] will review and approve all submittals in this section requiring Government approval.

]1.5 QUALITY ASSURANCE

1.5.1 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship must be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.2 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products must have been in satisfactory commercial or industrial use for 5 years prior to bid opening. The 5-year period must include applications of equipment and materials under similar circumstances and of similar size. The product must have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 5-year period. Where two or more items of the same class of equipment are required, these items must be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.2.1 Alternative Qualifications

Products having less than a 5-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.2.2 Material and Equipment Manufacturing Date

Products manufactured more than one year prior to date of delivery to site must not be used, unless specified otherwise.

1.5.3 Converter Drawings

****

NOTE: Provide a detail on the drawings that identifies the location, mounting and permitted maintenance access areas for each converter.

For Navy projects, include the bracketed options that require surface mounting against the wall, and prohibits rear access to converter.

****

Furnish scaled drawings of enclosure outline including front, top, side views, and overall dimensions. Include "maintenance envelope" dimensions confirming space limitations identified on the drawings[, and surface mounting flush against the wall.[Rear access for maintenance and repair purposes is prohibited]]. The "maintenance envelope" drawings must also indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices. Provide external power and control wiring, cabling, connector, and backplane interconnect drawings. Provide single line, schematic, and wiring diagrams. Drawings must include details of input and output circuit breakers, contactors, rectifiers, surge protectors, control devices and conduit entry and exit locations. If parallel operation is included, provide an interconnection diagram. Submittals must include the nameplate data, size, and capacity.

1.5.4 Qualifications of Manufacturer

****

NOTE: The experience clause in this section has been approved by a Level I Contracting Officer in accordance with the requirements of Naval Facilities Acquisition Supplement (NFAS). NFAS can be found at the following link:

https://www.navfac.navy.mil/products_and_services/sb/opportunities/guidelines/navfac.html

This clause may be used without further approval or request for waiver.

****

Submit a certification stating that the manufacturer has a minimum of five years' experience in the design, manufacturing, and testing of 400 Hz solid state frequency converters at the equivalent or greater kW and voltage ratings for direct connection to aircraft electrical loads. When specifications require multiple converters operating in parallel, the manufacturer must provide specific experience with equal or greater kW rated converters.

Experience in manufacturing motor generator sets does not qualify as equivalent. Experience in manufacturing portable engine-driven 400-hertz power units does not qualify as equivalent. The manufacturer must be experienced in producing units for installation in permanent buildings in environmentally closed spaces or in weatherproof enclosures as applicable. The manufacturer must also document that converters are designed for connection to non-linear loads typically encountered in the aircraft and shipbuilding industries. The manufacturer must furnish documented experience with converters in various environmental conditions including exterior flight line, hangar, and environmentally enclosed spaces within buildings.

1.5.5 Work Plan

Submit a written work plan with the initial shop drawing submittal, which consists of a schedule of dates of the routine and special factory tests,

installation of equipment, field tests, and operator training for the system. Furnish a list of the test instrumentation equipment complete with the documented calibration program, for the factory and the field tests.

1.5.6 Routine Factory Test Plan

****
NOTE: Coordinate calendar day requirements with Activity and with special review requirements.
****

Submit test plan and procedures at least [21][_____] calendar days prior to the tests being conducted. Provide detailed description of test procedures, including test equipment and setups complete with their current calibration dates, to be used to ensure the converter meets this specification and explain the test methods used. As a minimum, include the tests required under the paragraph ROUTINE FACTORY TESTS.

1.5.7 Special Factory Test Plan

Submit the Special Factory Test Plan and procedures with the Routine Factory Test Plan. Provide detailed description of test procedures, including test equipment and setups complete with their calibration dates, used to ensure the converter meets this specification and explain the test methods used. As a minimum, include the tests required under the paragraph SPECIAL FACTORY TESTS.

1.5.8 Field Test Plan

****
NOTE: Coordinate calendar day requirements with Activity and with special review requirements. For Navy projects, use 30 days to coordinate with NAVAIR requirement to have time to arrange attendance.
****

Submit test plan and procedures at least [30][15][_____] calendar days prior to the start of field tests. Provide detailed description and dates and times scheduled for performance of tests, and detailed description of test procedures, including test equipment and setups of the tests to be conducted to ensure the system meets this specification. List make, model, and current calibration dates, and provide functional description of the test instruments and accessories. Explain the test methods to be used. As a minimum, include the tests required under the paragraph FIELD QUALITY CONTROL. Test reports must include power quality measurement data collected in accordance with IEEE 1159.

1.5.9 Nationally Recognized Testing Laboratory (NRTL) Listing

****
NOTE: Choose the bracketed "Combination" option only for Army projects, and only when the converter also has a separate 28 VDC Power output.
****

[Frequency][Combination] converters must be identified with a nationally recognized testing laboratory (NRTL) label or UL label prior to shipping.

1.5.9.1 Currently Listed Products

Submit NRTL or UL certification or UL file number for the actual [frequency][combination] converter to be shipped with the initial submittal to verify compliance of equipment.

1.5.9.2 Proposed Listed Products

Submit NRTL or UL certification or UL file number for same or similar rating or product size range of like design unit with the initial submittal to verify compliance of equipment.

1.5.10 Routine Factory Tests Certification

****
NOTE: Coordinate calendar day requirements with Activity and with special review requirements. Choose the bracketed "Combination" option only for Army projects and only when the converter also has a separate 28 VDC Power output.
****

Submit within [45][_____] calendar days after completion of tests. Receive approval of test prior to shipping unit. Certify tests were conducted on each [combination] converter in accordance with the requirements set forth in paragraph ROUTINE FACTORY TESTS and certify converter satisfactorily operated within specified limits. Include copies of the test procedures,test configuration diagrams and schematics, test data, and results.

1.5.11 Special Factory Tests Certification

****
NOTE: For Army projects, choose the bracketed "Combination" option only when the converter also has a separate 28 VDC Power output.
****

Certify tests were conducted on a [combination] converter of the same design, construction, kW rating, and voltage rating to be provided. Tests must be in accordance with the requirements set forth in paragraph SPECIAL FACTORY TEST and certify converter operated without malfunctioning within specified limits. Include copies of the test procedures, test configuration diagrams and schematics, test data, and results.

1.5.12 Field Test Certification

****
NOTE: Coordinate calendar day requirements with Activity and with special review requirements. Choose the bracketed "Combination" option only when the converter also has a separate 28 VDC Power output.
****

Submit report of test results as specified by paragraph FIELD QUALITY CONTROL within [15][_____] calendar days after completion of tests. Certify tests were conducted on each [combination] converter in accordance with the paragraph FIELD QUALITY CONTROL and certify converter

satisfactorily operated within specified limits. Include copies of the test procedures, test configuration diagrams and schematics, test data, and results.

1.6 OPERATION AND MAINTENANCE MANUALS

****
NOTE: Choose the bracketed "Combination" option only on Army projects and only when the converter also has a separate 28 VDC Power output. Coordinate the 28 VDC options throughout the specification based on the actual equipment required and specified.
****

Submit [frequency][combination] converter Operation and Maintenance Manuals (O&MM) in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

1.6.1 Additions to Converter O&MM

****
NOTE: Include the paralleling bracketed option when paralleling has been included as a requirement of the equipment.
****

In addition to requirements of Data Package 5, include the following on the actual converter provided:

a. A "one-line diagram" from the building service entrance panel to the converter and out to the end utilization point(s).

b. A concise, duplicatable, single page data sheet with operating instructions for each unit including startup[, paralleling,] and shutdown procedures.

c. Routine and field test reports.

d. NRTL or UL certification or UL file number.

e. A list of all code required identification and warning signage and labels that have been provided on the converter.

1.6.2 Preliminary Converter O&MM

Prior to scheduling Field Tests, 2 bound copies of a Preliminary O&MM must be submitted to and approved by the Contracting Officer.

1.6.3 Spare Parts Information

Furnish recommended manufacturer's spare parts list, quantities, lead time to receive after ordering, and a schedule of prices,(guaranteed for one year after warranty expires), for each type of converter and other equipment specified in this section. Include the following:

a. Fuses

b. Human Machine Interface (HMI)

c. Indicator lamp/LED

d. Output switching modules

e. Plug-in logic cards

f. Power filter capacitors

g. Power semi-conductors

h. Ventilation system filters

i. 400 Hz Aircraft Power Cable Assembly

[j. 28 VDC Aircraft Power Cable Assembly

]1.7 WARRANTY

The equipment items must be supported by service organizations which are most convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

PART 2 PRODUCTS

2.1 [FREQUENCY][COMBINATION] CONVERTER

****

NOTE: Do NOT edit this paragraph to specify the internal architecture of the converter (e.g. type of power supply, rectifier type or switching technology to be utilized). Specifying this type of technology may make this a sole source specification which requires justification and approval per federal contract law.

For the options: Choose the bracketed "Combination" option only for Army projects and only when the converter also has a separate 28 VDC Power output. Choose 50 or 60 Hz based on the exterior power distribution system at the project location. Choose 24,000 for the MTBF unless the project has documented, more stringent requirements.

****

Provide [frequency][combination] converter consisting of modular construction solid-state components for [50][60] Hz to 400 Hz [and 28 VDC] conversion, input/output devices, and ancillary control devices. Converter must be a standard product of the manufacturer and the manufacturer's latest design that complies with the specification requirements. The converters provided under this contract must be products of the same manufacturer. Each unit must have a calculated Mean Time Between Failures (MTBF) exceeding [24,000][_____] hours as calculated when the converter is provided with yearly servicing and maintenance. Provide converter with NRTL or UL listing complying with UL 1012. The converter must have minimum 12 pulse, active input rectification circuit or a demonstrated design achieving equal or better performance characteristics. Circuit breakers operating at 400 Hz [and 28 VDC] must

be designed and UL tested for [50][60] Hz operation and derated for 400 Hz operation[and 28 VDC operation, as appropriate]. Provide startup and shutdown instructions posted on the front of the unit using engraved plastic or aluminum plate. Provide a plastic encapsulated schematic diagram attached to the inside of the unit in clear view of maintenance personnel.

2.1.1 Electrical Characteristics

2.1.1.1 Input Voltage

****
NOTE: For units 15 kW and below, the input voltage should be 208 volts. For units over 15 kW, the preferred input voltage is 480 volts. Using input voltage other than 480 volts will increase the cost and weight and decrease the efficiency of the converter. Show input voltage on the construction drawings.

Choose 50 or 60 Hz based on the exterior power distribution system at the project location. Choose 10 percent voltage variation unless specific project documents require a higher percentage input variation to be permitted.

A voltage changing transformer is not permitted at the input of the converter unit on any new facilities. Adding a voltage changing transformer at the input is only permitted in the rare case when retrofitting an existing facility and there is no other voltage available. In this exception, remove the last sentence in the section below.
****

[480][208][380][_____] V, three phase, three wire, grounded, [60][50] Hz. Converter must provide rated output voltage when input voltage is varied plus or minus [10][_____] percent. A voltage changing transformer is not permitted at the input of the converter unit

2.1.1.2 Input Power Factor

Between 0.8 lagging and unity, under all conditions of steady state line and load variations specified herein.

2.1.1.3 Surge Protection

****
NOTE: Select Location Category C for outdoor locations only.
****

Provide converter capable of sustaining an input surge described in and tested in accordance with UL 1449, and IEEE C62.41.1 and IEEE C62.41.2, Location Category [B][C], and continue to operate with no alarms within the specified tolerance.

2.1.1.4 Inrush Current

The inrush current must not exceed 100 percent of the rated full load input current.

2.1.1.5 Input Current Distortion

****

NOTE: Where total connected frequency converter load is a small percentage (less than 40 percent) of the total connected facility load, use 12 percent Total Harmonic Distortion (THD) and 8 percent individual. For large frequency converters (e.g. existing systems with 312 kW or larger) or where total connected frequency converter load is a significant percentage of the total connected facility load, use 5 percent THD and 3 percent individual. For installation in shipboard environments using Type 1 power (60 hertz per MIL Std 1399), use 5 percent THD and 3 percent individual.

Note that per NAVAIR request, the converter Special Tests paragraph requires data to be provided at the 25, 50, 75 and 100 percent load points. This is intentionally more stringent than the "full load" requirement below, and is intended for data acquisition only. It will be used to help develop a resolution to known field problems.

****

Input current Total Harmonic Distortion (THD) must not exceed [12][5] percent of the fundamental frequency with nominal input voltage at full load. Individual harmonic content must not exceed [8][3] percent of the fundamental frequency.

2.1.1.6 Output Voltage

****

NOTE: 1) Choose the first bracketed optional paragraph unless a combination unit is required on an Army project.

(a) Select the voltage requirement based on the Activity's location.

(b) Use MIL-STD-704, when 400 Hz power is required to power aircraft avionic equipment. Aircraft equipment is normally operated 200Y/115 V, three-phase, 400 Hz, grounded. Aircraft power monitors are only compatible with 200Y/115 Volts.

(c) If the voltage drop calculations (because of a required location of avionics shop units) are excessive, manufacturers upon request, are able to provide an avionics shop unit with 120/208 VAC output.

(d) Use MIL-STD-1399-300, Part 1 when 400 Hz

power is required to power laboratory test benches simulating shipboard environments. Shipboard equipment in simulated shore laboratory environments is normally operated on a 440 V, three-phase, 400 Hz, ungrounded system.

(e) Select the "A-B-C" phase rotation option for MIL-STD-704, and the "AB-BC-CA" option for MIL-STD-1399-300.

2) Choose the second bracketed "Combination" option only for Army projects when the converter also has a separate 28 VDC Power output.

****

[Provide a frequency converter with a [200Y/115 V, three phase, 400 Hz, grounded][440 V, three phase, 400 Hz, delta connected ungrounded] system, adjustable to plus or minus 10 percent of the rated voltage.

[a. The power characteristics must be within the requirements of MIL-STD-704 with the following clarifications:

(1) The voltage and frequency must be in accordance with the envelope of normal operating range of Figures 3 and 5, not just the limits of Figures 4 and 6.

(2) The steady state voltage must additionally be in accordance with the external power requirements as defined in the MIL-STD-704 Section 4.3, "External Power Source Requirement".

][b. The power characteristics must be within the requirements of MIL-STD-1399-300, Part 1, Type III power.

c. The phase rotation of the output voltage must be [A-B-C][AB-BC-CA] (per Figure 2 in MIL-STD-704, spinning in a counterclockwise direction).

]][Provide a combination converter with both 400 Hz and 28 VDC voltages deliverable simultaneously from the converter on individual outputs.

a. The 400 Hz output must be a 200Y/115 V, three phase, 400 Hz, grounded system, adjustable to plus or minus 10 percent of the rated voltage.

b. The 28 VDC, must be adjustable between 24 and 32 VDC.

[c. The power characteristics must be within the requirements of MIL-STD-704 with the following clarifications:

(1) For the 400 Hz output, the voltage and frequency must be in accordance with the envelope of normal operating range of Figures 3 and 5, not just the limits of Figures 4 and 6.

(2) For the 28 VDC output, the voltage must be in accordance with the envelope of normal operating range of Figure 13, not just the limits of Figure 14.

(3) The steady state voltage must additionally be in accordance with the external power requirements as defined in the MIL-STD-704 Section 4.3, "External Power Source Requirement".

(4) The 28 VDC must additionally be in accordance with the requirements as defined in the MIL-STD-704 Section 5.3.2.4, "Electric Starting".

][d. The power characteristics must be within the requirements of MIL-STD-1399-300, Part 1 Type III power.

] e. The phase rotation of the output voltage must be [A-B-C][AB-BC-CA] (per Figure 2 in MIL-STD-704, spinning in a counterclockwise direction).

]2.1.1.7 Power Output

****

NOTE: Previous versions of this specification referred to equipment sized only in kVA at 0.8 lagging power factor. The specification now has the requirement to use kW instead of kVA as the unit of power measurement for converters here and on the project drawings. This is a significant change in equipment designation, intending to ensure that our equipment meets the full required load range, including full power at unity power factor. It has been made to eliminate the problems that have been occurring with existing equipment in the field, and to accommodate the increasing nonlinear load characteristics of Military equipment. NAVAIR documents, including their Facilities Requirements Documents (FRD)s, are being revised to coordinate with this change to kW. Army documents are in the review process.

Size units that provide power for aircraft based on the type and number of aircraft to be supplied. Point of Use converters are required.

For Navy Projects, choose the first bracketed option. Use 90 kW for all fixed wing aircraft and use 45 kW for all rotary wing aircraft unless there are specific project design requirements approved by NAVFAC and NAVAIR. (One example, may be the direct replacement of an existing, larger kW converter.)

For Army projects, use the first bracketed option except when a combination converter is required.

****

[Provide a frequency converter rated at [_____] kW at unity power factor.] [Provide a combination converter rated for continuous, simultaneous outputs of [_____] kW of 400 Hz at unity power factor and [_____] amps at 28 VDC. Combination converter must have a [_____] amp 28 VDC starting capacity for one minute.]

2.1.1.8 Load Range

****

NOTE: The intent of the load description below with the 15 percent current THD is to portray a 50

percent linear and 50 percent non-linear load, with a nonlinear load designed to emulate a six pulse rectifier supplying a resistive load. See UFC 3-555-01 App "xx" (Draft in Progress) for an example of the non-linear loadbank schematic. This loadbank would be used to validate factory testing requirements.

****

Converter must operate into a linear load with a power factor between 0.5 lagging and 0.7 leading and into a non-linear load with not less than 15 percent current THD, composed of not less than 6 percent of the 3rd harmonic and not less than 7 percent of the 5th harmonic.

2.1.1.9 Efficiency

****

NOTE: Use the table below to fill in the kW and the minimum efficiency.

Minimum Percent Efficiency		
Rating (kW)	50 Percent Load	100 Percent Load
5 - 14	80	90
15 - 39	86	90
40 - 99	87	91
100 - up	89	92

Electromagnetic Interference (EMI) filtering is rarely required, and has been removed from this specification. However, if EMI is needed for a specific project, and is added back into the specification, then for units with power rating larger than 15 kW, reduce the minimum efficiency by 2 percent.

In the rare case when a project is "permitted by exception" to have a voltage changing transformer at the input of the converter, reduce the specified efficiencies by 2 percent.

****

Provide [_____] kW units with a minimum efficiency of [_____] percent at 50 percent load and [_____] percent at 100 percent load.

2.1.1.10 No Load Input Losses

****

NOTE: Above 30 kW, use 7 percent. Below 30 kW, use 9 percent.

In the rare case when a project is "permitted by exception" to have a voltage changing transformer at the input of the converter, increase the specified no load input losses by 2 percent.

****

Provide frequency converter with no-load input losses no greater than [7] [9][_____] percent of the output kW rating.

2.1.1.11 Overload

****

NOTE: For the Navy, include the bracketed 300 percent overload requirement in the table. However, units strictly for avionics shop use do not need the 300 percent requirement.

****

Satisfactory overload operating time is based on no more than one overload of the same or longer conditions, within the following specified time between overloads.

Percent of Full Load	Satisfactory Operating Time	Time Between Overloads
110 percent	60 minutes	4 hours Note: Unit must still be capable of withstanding any of the other conditions for their respective operating times. e.g. Unit can still do 125 percent for less than 5 minutes, before tripping, etc.
125 percent	5 minutes	10 minutes
150 percent	2 minutes	10 minutes
200 percent	20 seconds	5 minutes
[300 percent	4 seconds	5 minutes]

After minimum operating time is achieved, unit must interrupt output power. Unit must be capable of sustaining the overload without damage until the protective device interrupts the overload.

2.1.1.12 Short Circuit

When a bolted line-to-line fault or a bolted three phase fault is applied to the unit, unit must be capable of sustaining the short circuit current without damage until the protective device interrupts the fault.

2.1.1.13 Crest Factor

The voltage crest factor must be between 1.31 and 1.51 over the entire load range in accordance with MIL-STD-704. The crest factor is the ratio of the peak value to the root mean square (RMS) value for each half cycle of the voltage waveform measured over a one second period under steady state conditions. Provide the crest factor for each condition in the paragraph LOAD RANGE.

2.1.1.14 Output Voltage THD

****

NOTE: The values indicated below meet MIL Std 704 requirements. Specifying lower percentages of THD requires more stringent power quality, may be a significant cost addition, and should only occur when a specific installation has different documented power quality requirements.

****

a. Balanced load:

(1) Output voltage THD: Not to exceed [3][_____] percent line-to-line and line-to-neutral for linear loads as specified in the paragraph LOAD RANGE.

(2) Output voltage THD: Not to exceed [5][_____] percent line-to-line and line-to-neutral for non-linear loads as specified in the paragraph LOAD RANGE.

(3) Maximum single harmonic distortion: Not to exceed [2][_____] percent of the fundamental at the nominal voltage for linear loads as specified in the paragraph LOAD RANGE.

(4) Maximum single harmonic distortion: Not to exceed [3][_____] percent of the fundamental at the nominal voltage for non-linear loads as specified in the paragraph LOAD RANGE.

b. Unbalanced load: Output voltage THD not to exceed 4 percent, line-to-neutral with 15 percent unbalanced linear load.

2.1.1.15 Output Voltage Amplitude Modulation

Provide output voltage amplitude modulation not exceeding 1/2 percent of nominal voltage at no load to full load.

[2.1.1.16 Voltage Regulation for Combination Converters with Multiple Outputs

****

NOTE: Combination Converters and Dual output converters are not permitted for Navy Projects. Navy requirement is for individual Point of Use Converters (PUCs).

For Army projects:

1) Dual output 400 Hz converters are no longer permitted.

2) When a combination converter (400 Hz and 28 VDC) is specified, verify with the Activity whether the converter will have a "simultaneous" or a "non-simultaneous" rating.

Include this voltage regulation option when the unit is required to simultaneously provide individually regulated power to each of the different voltage

outputs (400 Hz and 28 VDC). It may add significant cost and size to the converter.

(a) Simultaneous regulation ensures that the voltage at the end of output A does not change if: Output B is turned on or off; or if there is an increase or a decrease in the load on output B. This would not apply to system overloads and short duration transients.

(b) "Non-simultaneous" regulation applies where either the rated 400 Hz Output or the 28 VDC output is available and regulated, but not both at the same time.

****

For combination converter systems that provide 400 Hz and 28 VDC power each output must have isolated voltage regulation. The output voltage measured at the end of one servicing cable must not rise or fall as a result of any change in status of additional outputs (e.g. second output goes from ON to OFF, OFF to ON, or increase/decrease in applied load.) Voltage fluctuations as a result of short duration transients (non-steady state limits/times in accordance with MIL-STD-704) are exempt from this requirement.

]2.1.1.17 Frequency Stability

Control output frequency of the 400 Hz converter within plus or minus 0.5 percent for all operating conditions, including maximum and minimum specified input voltages, ambient temperature and relative humidity. The frequency regulation must operate independent of supply frequency and load changes.

2.1.1.18 Phase Angle Regulation

Displacement angle between adjacent voltage phases must be 2.1 radians 120 degrees plus or minus 0.035 radians 2 degrees with balanced load and plus or minus 0.07 radians 4 degrees with three phase 15 percent unbalanced load. A 15 percent unbalanced load is defined as any combination of phasing where:

a. Phase A at full rated single phase load.

b. Phase B at 85 percent of Phase A.

c. Phase C at 85 percent of Phase A.

2.1.1.19 Transient Output Voltage Recovery

****

NOTE: Use MIL-STD-704, when 400 Hz power is required to power aircraft avionic equipment.

Use MIL-STD-1399-300, when 400 Hz power is required to power shipboard equipment.

****

[In accordance with MIL-STD-704.][In accordance with MIL-STD-1399-300 for Type III power.]Monitor and record output voltage at the load end of

the cable.

2.1.2 Environmental Rating

****

NOTE: Select 55 degrees C 130 degrees F (ambient temperature rating unless in areas subject to extreme temperatures (e.g. Middle East or desert environments). Use 0-95 percent relative humidity unless extreme condensation such as in a jungle climate.

Use 915 meters 3000 feet level unless location of installation will be at higher elevations.

****

The converter must be rated for continuous operation from no load to rated full load under the following conditions:

a. Ambient temperatures ranging from -20 to [55][60][65] degrees C. -4 to [130][140][150] degrees F.

b. Relative humidity from [0 to 95] [_____] percent noncondensing.

c. Ambient pressures from sea level to [915] [_____] meters [3,000] [_____] feet.

2.1.3 Monitoring and Control Panel

Provide converter with a control panel that is equipped with the following controls, indicators, instrumentation, data logging, diagnostics, and alarm functions.

2.1.3.1 Controls

Controls must be mounted on the front of the control panel, accessible without opening any doors or covers. Specific sequencing, or the requirement for simultaneous pushbutton operation, is not acceptable for any input or output control.

****

NOTE: Include the remote control panel option when unit is platform mounted or located out of sight of aircraft.

****

a. Start/stop pushbutton for input device control (circuit breaker or contactor).

b. Lamp/light emitting diode (LED) test - A push-to-test button or switch to test indicator lamps/LEDs. If panel lights all blink as part of the startup Built-in-Test (BIT) sequence, then a separate push to test button is not required.

c. Emergency power off - A separate pushbutton for emergency power off.

d. Output device ON/OFF.

e. Alarm silence and "silence" indicator - A switch that must disable the

audible alarm without clearing the alarm codes.

f. Additional individual controls for the following functions (Note - these may be included as part of the Human-Machine Interface (HMI) as described in paragraph HUMAN MACHINE INTERFACE REQUIREMENTS):

- Output voltage adjust

- Alarm reset - resets and clears the silenced audible alarm.

2.1.3.2 Indicators

a. The following are mandatory indicators. They must be included on the control panel on the exterior of the unit[, and on the exterior of the remote control panel] in addition to any that are included in the HMI:

- Input power available - Lamp/LED to indicate that the supply voltage is available.

- Output power On/Off - Lamp/LED to indicate that the converter output voltage is available.

- Output device "ON".

- Audible alarm.

- Aircraft interlock bypass - Lamp/LED to indicate that the Aircraft Interlock has been bypassed.

b. In addition, include the following additional indicators, if they are not included in the HMI:

- System alarm - Lamp/LED to indicate that a fault has been detected. This indicator must be latched in the "ON" position whenever an alarm condition described in paragraph ALARM ANNUNCIATOR, is detected and must remain "ON" until the alarm reset pushbutton is pressed.

- Indicating lamp/LED to indicate that the alarm silence switch is in the disable position.

- Elapsed time meter in hours; (may be internal or visible externally).

2.1.3.3 Human Machine Interface (HMI) Requirements

****
NOTE: For rarely used delta output frequency converters, delete the phase-to-neutral voltage requirement below.
****

Provide an HMI with a minimum of four by twenty (4 x 20) character backlit LED display for presenting the digital instrumentation, diagnostic system, and fault indicating system data. The HMI must be rated for harsh environments.

a. Digital Instrumentation. Provide true RMS, plus/minus one percent accuracy, microprocessor-based readings that include the following functions:

(1) Output phase-to-phase voltage.

(2) Output phase-to-neutral voltage.

(3) Output phase current.

(4) Output frequency.

(5) Inverter temperature. This function is desired for field diagnostics, but is not mandatory.

b. Alarm Annunciator. The unit must be capable of detecting and displaying the following abnormal conditions:

(1) Input overvoltage.

(2) Input undervoltage.

(3) Output undervoltage.

(4) Output overvoltage.

(5) Output overload.

(6) System alarm.

(7) Control logic failure.

(8) Over-temperature.

(9) Logic power supply failure.

2.1.4 Input/Output Devices

****
NOTE: Coordinate 50 Hz vs 60 Hz requirement with Activity. Provide appropriate short circuit ratings in accordance with Basis of Design Calculations per UFC 3-501-01, "Electrical Engineering".
****

Provide fully-rated, three-pole, UL approved devices for control of [60][50] Hz input and 400 Hz output from the converter. Derate devices and cables operating at 400 Hz in accordance with IEEE 519.

2.1.4.1 Input Device

Provide converter with a UL listed input device (circuit breaker conforming to requirements of UL 489 or contactor) as an integral part of the converter. Device must be operable from the front of the converter. Device must have a short-circuit current rating of [_____] amperes symmetrical minimum.

2.1.4.2 Output Contactor

****
NOTE: Include option for IEC on Oconus projects.
****

Provide converter output with an automatic magnetically-held contactor with interlock circuit. Output contactor must have sufficient capacity to handle rated load, overload, and available short circuit current. Contactor must open when any circuit identified in the paragraph SAFETY FUNCTIONS causes the system to shut down. Electrically interlock contactor with ON/OFF circuitry so that when the frequency converter is shut down, the contactor opens immediately and remains open.[Conform to the requirements of IEC 60947-4-1.]

[2.1.4.3 Output Circuit Breaker

****

NOTE: Only add an output circuit breaker, (and delete the OUTPUT CONTACTOR paragraph above), if the converter is supplying a downstream distribution panelboard (such as in a shop or laboratory), or multiple outputs with distribution internal to the converter. Include the 28 VDC bracketed option only on Army projects with combination converters.

****

Provide converter output(s) with non-automatic manual circuit breaker(s), with appropriate frame size and a shunt trip coil derated for 400 Hz [and 28 VDC] operation. Trip circuit breaker by the unit's OFF circuit [local or remotely activated] and when any circuit identified in the paragraph SAFETY FUNCTIONS causes the system to shut down. Output breaker(s) must be operable from the front of the unit.

]2.1.4.4 Aircraft Interlock Circuit

****

NOTE: Coordinate with paragraph AIRCRAFT POWER CABLE ASSEMBLY.

1) For all new installations, use the first bracketed option; "Provide a Split F Type safety insertion interlock ..." in the first paragraph, and use the Split F option in item b.(1) "Normal...". See UFC 3-555-01 (Draft in Progress) and MIL-DTL-32180 for technical information and typical details and schematics on the operation of the interlock.

2) When the aircraft cable specification is used for existing converters, coordinate with the Activity to ensure they understand the new safety requirements in the UFC 3-555-01 (Draft in Progress) and have appropriate Standard Operating Procedures (SOPs) in place, per UFC 3-560-01, Operational and Maintenance: Electrical Safety" for the remainder of their existing equipment.

3) The 1997 NATO document "STANAG 7073", (titled Connectors for Aircraft Electrical Servicing Power) requires the EF pin to be jumpered in the ground servicing cable connector. The use of the Split F Insertion Interlock will meet that requirement.

For the Air Force: When involved with certain

"Legacy" Air Force Aircraft, they may use the "STANAG" Alternate connection circuit, and the 28 VDC may need to be changed to utilize one of the 115 V, 400 Hz phases instead. Coordinate with the Activity to confirm requirements.

****

[Provide a Split F Type safety insertion interlock system (with the contacts integral to the cable head) in accordance with MIL-DTL-32180.

Utilize a control signal established by the converter to determine whether the servicing cable connector is installed to the aircraft or not. The converter control system must prevent the output control device from closing if the 28 VDC signal is not present. If the converter output control device is closed when the 28 VDC signal is lost, the converter control system must remove the 400 Hz power from the output servicing cable connector within 100 milliseconds. This 28 VDC control signal must not be referenced to the aircraft and cannot affect components on the aircraft.

][Provide interlock system that determines the presence or absence of the 28 VDC feedback signal from the aircraft. If the 28 VDC signal is not present within 5 seconds after initially closing the output disconnect, open the output disconnect. Once the interlock signal is received and the system is in operation, if the interlock signal is lost, the converter control system must remove the 400 Hz power from the output servicing cable connector within 100 milliseconds.

] a. Converter must contain terminal block points for the connection of two wires from the aircraft cable assembly for the interlock circuit (sized to accept No. 18 and No. 12 AWG). Interlock circuit must not draw more than 20 milliamperes from the aircraft's 28 VDC circuit.

b. For field testing purposes, provide a switch inside the converter with two positions:

(1) Normal - [Converter relying on signal from Split F connecter][For aircraft loads].

(2) Bypass - For testing with dummy load or no load, or for use with aircraft with no 28 VDC. This switch needs to be "Inside" or "located within the HMI functions". It must be out of sight except for specific maintenance purposes.

2.1.5 Safety Functions

2.1.5.1 400 Hz Power Source

The 400 Hz power source internal buss must automatically discharge to below 30 VAC within 5 seconds after the following:

a. 400 Hz power source has been turned off.

b. Whenever any access panel is opened on the equipment. Under this condition, the interlock circuitry must open the input device and the 400 Hz output device, and not allow the input or output device to close. For maintenance purposes, provide an internal bypass switch to defeat the interlock circuitry.

c. Detection of system fault that results in a converter shut down condition, including the following:

(1) Input undervoltage.

(2) Input overvoltage.

(3) Loss of phase (input or output).

(4) Loss of input power.

2.1.5.2 400 Hz Output Cable

The 400 Hz power must be removed from the output cable within 100 milliseconds after one of the following occurs:

a. Receiving a stop command.

b. Loss of 28 VDC control signal.

c. Detection of a fault that results in an output shut down, including the following:

(1) Output overvoltage - Protect by tripping output devices for instantaneous overvoltage of 30 percent or more and for 10 to 30 percent overvoltage lasting more than 0.25 seconds.

(2) Output undervoltage - Protect by preventing the closing of the output disconnect until the output voltage is 95 percent of the rated output. If, after closing, the voltage decreases to below 90 percent for longer than 5 seconds, provide relaying to trip output devices utilizing a field-adjustable time-delayed circuit with a range of 4 to 10 seconds.

(3) Output frequency - Protect by tripping output devices for frequency change in excess of plus or minus 5 percent of the rated output frequency (400 Hz).

(4) Output overload.

(5) Converter overtemperature protection.

2.1.6 Automatic Line Drop Compensation

Provide automatic line drop compensation from zero to ten percent; adjustable internally.

[2.1.7 Paralleling

****

NOTE: This is an additional cost item and should not be specified unless specifically requested by the user. Coordinate with the Activity on desired load sharing percentages, and on whether or not the manual paralleling bracketed option is needed.

****

Provide frequency converters capable of being paralleled. Paralleled units must be the same manufacturer and model number. Regulate and

control units operated in parallel by a master unit. Design controls associated with paralleling of the units such that each frequency converter can operate as a stand alone unit, or as either a slave or master unit in a parallel system. Units must parallel and synchronize within a 50 millisecond recovery time. Share the total load equally within plus or minus [5][_____] percent by each unit. If paralleling for redundancy, failure of one system must not affect the other system(s).[Provide manual paralleling which permits a paralleled unit to be added or removed from the system without interrupting the operation of other units.]

][2.1.8 Auto Restart

****

NOTE: Auto restart should be considered when the converter is installed in a remote location that is not readily accessible to operating personnel and maintaining 400 Hz power is critical to operations. Use of auto restart should be studied carefully to ensure that it does not create a potential personnel safety hazard.

This is an additional cost item and should not be specified unless specifically requested by the user.

****

After a total input power outage the unit must be capable of automatically restarting and re-energizing loads upon restoration of normal power. Provide units with a manual/auto restart switch and with backup battery power supply if it is needed to meet the auto restart requirement. When interlock circuit has been interrupted or when interlock is in the maintenance position (manual restart), the system should not restart.

][2.1.9 Built-In Test Equipment

****

NOTE: Built-in test equipment (BIT) should be considered when the converter is installed in a remote location that is not readily accessible to operating personnel and maintaining 400 Hz power is critical to operations. It may also be needed when high reliability is a defined concern.

This may be an additional cost item and although some manufacturers include it at no cost, it should not be required unless specifically requested by the user.

****

Frequency converter must include Built-in test equipment(BIT), which monitors both primary circuits and protection circuits of the unit. Provide visual indication to assist diagnosis of unit failures to a modular level. Provide visual indication of converter status using cabinet mounted light emitting diodes and Human Machine Interface (HMI). As a minimum the indicator lights must include a "machine on" light, and an "output faulted" indicator light that comes on when the unit has shut down.

]2.1.10 Magnetic Components

****

NOTE: Magnetic components are used within the converter unit. Do not delete this information. It is not included to imply permission to utilize transformers for modifying the input voltages to the converter.

****

Provide Class 180 power magnetic transformer and inductors in accordance with NEMA ST 20 and UL 506. The limits of Class 180 must not be exceeded at the maximum specified ambient temperature and at 100 percent load.

2.1.11 Acoustical Noise

****

NOTE: The following table serves as a guide for establishing the maximum allowable sound pressure level for each kW rating. The designer should take into consideration that converters are inherently noisy when physically locating the unit. Per manufacturers, 72 dBa is standard across the range of converters we specify.

Specifying one of the optional "Manufacturers Lowest Attainable - Maximum Acoustical Noise Values", which per the table below is possible, will have an additional cost associated with it.

Acoustical Noise Table

Rating (kW)	Mfrs Standard - Maximum Acoustical Noise Values (dBa)	Mfrs Lowest Attainable - Maximum Acoustical Noise Values (dBa)
5 - 14	72	65
15 - 39	72	65
40 - 99	72	68
100 - 249	72	72
250 - up	72	

NOTE: Do not go below the table values, unless specifically required by the Activity because of the location of the frequency converter, and unless the new values have been confirmed by multiple manufacturers as attainable.

If any value different than 72 dBa is used, include the "optional Acoustical Noise Test" in paragraph SPECIAL FACTORY TESTS, to verify that the equipment furnished meets the more stringent requirement. The test parameters (height and range) are included in

that paragraph.
****

Provide unit with a maximum continuous acoustical noise level less than [72][_____] dBa (A weighted scale).

2.1.12 Assembly Construction

****
NOTE: Per manufacturers, all converter enclosures require ventilation. Per NEMA 250 Tables 1 and 2, only NEMA Types 1,2,3R and 3RX are permissible to be ventilated. Verify availability by multiple manufacturers before using other enclosure types.

When location is outdoors, include the appropriate outdoor location coating and painting options.

When location is indoors, in item a:
- For Navy and Air Force, choose first option requiring flush wall mounting.
- For Army, choose second option and identify if pedestal mounted in hangars or floor mounted in lab or other locations.
****

Provide enclosures suitable for [indoor][outdoor][corrosive][direct spray] [_____] environments in accordance with NEMA 250, Type [l][2][3R][3RX]. Arrange to provide required louvers, cooling air, entry and exit provisions for equipment within enclosures.

a. [Units must be mounted flush against the wall, must not require back access for maintenance, and must comply with the "Maintenance Envelopes" identified on the drawings.][Units must be [pedestal][floor] mounted as indicated and comply with the "Maintenance Envelopes" identified on the drawings.]

b. Construct unit(s) so that components, with the exception of control and monitoring components, are totally enclosed within the enclosure. Electronic circuits including power circuits must be modular construction readily accessible for maintenance, repair and module replacement from the front of the enclosure.[For units installed outdoors or in corrosive environments, [provide a conformal (rust-inhibiting) coating for the printed circuit boards][enclose electronic circuits in a sealed electronics compartment that is not provided with direct cooling ventilation or forced air cooling].]

c. Provide permanent identification tags for wiring. Uniquely identify each wire. Use the same identification system in the wiring diagrams in the Operation and Maintenance Manual. Enclosures must be painted in accordance with paragraph FACTORY APPLIED FINISH and as specified herein. Provide each enclosure with a finish coat over a rust inhibiting substrate or a substrate that has been provided with a rust inhibiting treatment.[For outdoor enclosures, if the unit is not painted using the powder coating process, provide two finish coats on the unit.]

d. Provide units with a Mean Time To Repair (MTTR) of 30 minutes from the time of the diagnosed failure based on documented manufacturer's

historical data for the average time of repair for their top ten faults. Provide the supporting data with the equipment submittal.

2.2 AIRCRAFT POWER CABLE ASSEMBLY

****

NOTE: Coordinate with paragraph AIRCRAFT INTERLOCK CIRCUIT. Banded cables are not permitted for 400 Hz systems due to excessive phase unbalance and voltage drop.

NOTE: For the Army:

1) Coordinate the cable amperage and length for the aircraft on the project.

2) Include the bracketed 28 VDC cable option when a combination converter, with an additional 28 VDC output, is part of the project.

NOTE: For the Navy:

1) Use the 260 Amp and 32 meters 105 feet length options for all cable assemblies with the 90 kW converters, and the 180 Amp 32 meters 105 feet length for all 45 kW converters, unless the project requirements given to the designer of record specifically identify that the 27 meters 90 feet feet length is sufficient.

2) Delete the 28 VDC option. Combination 400 Hz and 28 VDC Converters are no longer permitted. Individual 28 VDC Converters are required. Contact NAVFAC Atlantic, Code DC 44 - Criteria Manager at (757) 322-4327, for a draft 28 VDC specification that can be modified for the specific project.

****

Comply with SAE AS7974. For 400 Hz wiring at 200Y/115 volts, provide 7-conductor type cable configured as 6 phase conductors (2xA, 2xB, 2xC) tightly wound around the center located neutral, twisted and single jacketed in accordance with SAE AS5756/6. Rate cable for [260] [180] amperes. Cable length must be [32 meters] [27 meters] [_____] [105 feet][90 feet] [_____]. Provide control cabling included within the jacket for interlock circuit. Terminate control wiring on accessible terminal blocks in unit. Provide cable assembly with integrally molded 400 Hertz connector capable of connecting to the aircraft 6 pole receptacle. Provide cable/connector assembly suitable for severe duty, with crimped contact terminations. Banded cables are not permitted.

[2.2.1 28 VDC Aircraft Power Cable Assembly

For 28 VDC wiring provide 2-conductor cable assembly, banded in 600 mm 2 feet intervals maximum, in accordance with SAE AS5756. Provide cable assembly with integrally molded 28 VDC female connector aircraft plug in accordance with SAE AS7974.

][2.3 REMOTE MONITORING AND CONTROL PANEL

****
NOTE: Delete this paragraph unless plans clearly indicate requirement for remote monitoring and control panel.
****

Provide remote monitoring and control panel and circuitry. Connect to clearly and permanently labeled terminal blocks located inside the converter's enclosure. Provide the circuitry such that indicator lamp/LED information and control function(s) can be extended from the terminals to a remote location in the future.

a. Pushbutton or switch for de-energizing the output terminals.

b. Indicator lamp/LED showing the unit status (energized or not energized).

c. Indicator lamp/LED showing the output control device position (open or closed).

d. System alarm.

]2.4 MANUFACTURER'S NAMEPLATE

Each frequency converter, each major component within the frequency converter, and each item of other equipment must have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.5 FACTORY APPLIED FINISH

****
NOTE: This paragraph covers only the basic painting requirements for most electrical equipment. Include any special finishes for high or low temperatures and extremely corrosive atmospheres. Use manufacturer's standard color unless the Activity requires a special color.
****

Electrical equipment must have factory-applied painting systems which must, as a minimum, meet the requirements of NEMA 250 corrosion-resistance test and the additional requirements as specified herein. Interior and exterior steel surfaces of equipment enclosures must be thoroughly cleaned and then receive a rust-inhibitive phosphatizing treatment, a primer powder coat, or equivalent treatment prior to painting. Exterior surfaces must be free from holes, seams, dents, weld marks, loose scale or other imperfections. Interior surfaces must receive not less than one coat of corrosion-resisting paint or powder coating process in accordance with the manufacturer's standard practice. When enclosure is aluminum, interior may optionally be coated with rust inhibiting treated film. Exterior surfaces must be primed, filled where necessary, and given not less than two coats baked enamel with semigloss finish, or finished with a powder coating process.[Color must be the manufacturer's standard color.][Equipment located indoors must be ANSI Light Gray,[and equipment located outdoors must be ANSI[Light Gray][Dark Gray]].] Provide manufacturer's

coatings for touch-up work and as specified in paragraph FIELD APPLIED PAINTING.

2.6 SOURCE QUALITY CONTROL

2.6.1 Factory Test Schedule

****
NOTE: For the Army: Choose the bracketed "Combination" option (throughout the specification) only when the converter also has a separate 28 VDC Power output.
****

The Government reserves the right to witness tests and reserves the right to request the raw data from the tests whether witnessed or not. Provide the [frequency][combination] converter test schedule for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

Test Instrument Calibration.

a. The manufacturer must have a documented calibration program which assures that all applicable test instruments are maintained within rated accuracy.

b. The accuracy must be directly traceable to the National Institute of Standards and Technology.

c. Instrument calibration frequency schedule must not exceed 12 months for both test floor instruments and leased specialty equipment.

d. Provide dated calibration labels, that are visible on all test equipment.

e. Calibrating standard must be of higher accuracy than that of the instrument tested.

f. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

(1) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

(2) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.6.2 Routine Factory Tests

****
NOTE: Include the bracketed option, "As an exception..." when there are multiple, identically sized (in kW) converters on the same contract. Intent is to only do the "automatic line drop compensation test" on the first converter.

In item c, the aircraft power cable assembly is normally included in the project. If for some reason it is not part of the contract, modify the item and provide additional appropriate cable information (e.g. length and type) that the manufacturer should use for tests.

****

Perform routine tests by the manufacturer at the factory, on each of the actual [frequency][combination] converter(s) prepared for this project to ensure that the design performance is maintained in production.[As an exception, test automatic line drop compensation on only one unit on multiple unit orders of the same kW rating. If there are multiple units with different kW ratings, then testing one of each of the kW ratings is acceptable.] Submit test reports, by serial number and receive approval before delivery of equipment to the project site. Include a list of the current test equipment calibration dates. Required tests, test conditions, and testing sequence is as follows:

a. For tests which require full load, use 1.0 power factor unless otherwise noted.

b. All measurements must be true RMS measurements. Obtain measurements in accordance with IEEE 1159. Monitor and record all data at the load end of the cable.

c. Connect loads to the converter with the specified aircraft power cable assembly.

d. No adjustments to the frequency converter are allowed between load tests.

2.6.2.1 Test Conditions

Tests must include the following conditions:

a. Initial Safety Verification: Perform tests and checks to validate the safe and timely shutdown for each condition (for the power source and the output cable) identified in paragraph SAFETY FUNCTIONS.

b. Input current and power factor: Operate converter at low, nominal and high input voltage at full load. Measure and record input voltage, input power factor and input current in each phase.

****

NOTE: The non-linear load tests below are based on the requirements in the paragraph LOAD RANGE. The intent of the required 15 percent current THD in LOAD RANGE is to portray a 50 percent linear and 50 percent non-linear load, with a nonlinear load designed to emulate a six pulse rectifier supplying a resistive load. See UFC 3-555-01 Specialty Power Systems (Draft in progress) for additional information.

****

c. Output voltage, output voltage THD, output current, output power factor, and voltage regulation. Operate converter at nominal input

voltage unless otherwise specified.

(1) 50 percent of rated capacity with 0.8 lagging power factor linear load.

(2) 100 percent of rated capacity with 0.5 lagging power factor, 0.8 lagging power factor, 1.0 power factor, and 0.7 leading power factor linear loads.

(3) 50 percent of rated capacity with the non-linear load as specified in the paragraph LOAD RANGE.

(4) 100 percent of rated capacity at low and high input voltage.

(5) 100 percent of rated capacity with the non-linear load as specified in the paragraph LOAD RANGE.

(6) Note - Operate for not less than 10 minutes at each test condition in (1), (2), (3) and (4) above, and for not less than 30 minutes at test condition in (5) above.

(7) Note - Monitor and record each of the following at the beginning and end of each test condition: output voltage, output voltage waveform, output voltage THD, output voltage distortion spectrum, output voltage crest factor, output current, output current waveform, output current distortion spectrum, output power factor and frequency. Verify output remains within specified regulation limits.

d. Efficiency: Operate at nominal input voltage at half load and full load at 1.0 power factor. Measure and record input voltage, input current, input power factor, output voltage, output current, and output power factor. Calculate the unit efficiency.

e. No load losses: Operate at no load and nominal input voltage. Measure and record input voltage, input current, input power, input power factor, and output voltage. Calculate the no load losses.

f. Overload: Operate at nominal input voltage and output voltage with loads and in sequence listed below:

****

NOTE: For the Navy:

1) Include the bracketed 300 percent overload requirement in the table. However, converters strictly for avionics shop use do not need the 300 percent requirement.

2) Coordinate with NAVAIR (POC information is at front of specification), to see if the NAVAIR Digital File Information has been completed before including the bracketed documentation option.

****

Percent of Full Load	Time	Time Between Overloads	Iterations
[300 percent	4 seconds	5 minutes	3]
200 percent	20 seconds	5 minutes	1
150 percent	2 minutes	10 minutes	1
125 percent	5 minutes	10 minutes	1
110 percent	60 minutes	4 hours	1

Monitor output to confirm there is no 400 Hz power interruption. After minimum operating time is achieved, unit must interrupt output power. Provide voltage and current waveforms [in accordance with NAVAIR Digital File Information] documenting the unit's response for each test.

****

NOTE: Utilize the identified burn-in hours, unless a validated reason has been identified by the Activity (such as a requirement for a higher uptime confidence limit) to either reduce or increase the number of hours.

The last sentence in the BURN-IN TEST paragraph permits not using the Aircraft power cable assembly that has been mandated for all the other tests. This exception has been added because the specified cable may not withstand the current draw for this length of time without overheating.

****

g. Burn-in Test: Before delivery, burn-in all units[under full load conditions at 1.0 power factor for at least [24][_____] hours][by cycling units [6][_____] hours "ON" under full load conditions and [3][_____] hours "OFF" at no load conditions for at least [4][_____] complete "ON" cycles]. Perform burn-in test with the converter enclosure doors closed, load connected directly to the output terminals, and all ventilation in the final operating condition. The specified aircraft cable is not required to be used for this test.

****

NOTE: For the Army: Choose the bracketed option including the "frequency range of the individual harmonic occurrence".

****

h. Include harmonic frequency spectrum analysis depicting harmonic order across the range of individual harmonic occurrence,[and harmonic magnitude][harmonic magnitude, and frequency range of individual harmonic occurrence] for each load condition in the test reports. Conduct tests at the unit's input terminals (to the 37th harmonic), and at the units output terminals (to the 37th harmonic) per IEEE standards.

i. Automatic line drop compensation: Operate converter at nominal voltage and verify specified performance of the line drop compensation at the following loads.

(1) No-load.

(2) 50 percent of rated capacity with a 0.8 lagging power factor linear load.

(3) 50 percent of rated capacity with the specified non-linear load.

(4) 100 percent of rated capacity with a 0.8 lagging power factor linear load.

(5) 100 percent of rated capacity with the specified non-linear load.

j. Post Routine Test Safety Verification: Repeat tests conducted under item a. Initial Safety Validation to confirm safety features were not affected by previous tests.

2.6.3 Special Factory Tests (Design Tests)

****
NOTE: Include the bracketed option "each of" when there are multiple sizes of converters in the project.
****

Submit special factory test (design test) reports (complete with test data, explanations, formulas, results, setup and cable information, and the list of the calibration dates of the test equipment used), in the same submittal package as the catalog data and drawings for [each of] the specified frequency converter(s). Tests must be certified and signed by a registered professional engineer or by a "company certified professional designee" within the manufacturers' organization. Submit designee's credentials with the initial design test report for approval. Tests must be on file based on a production model of converters of the same design, construction and kW rating provided.

****
NOTE: Include the first bracketed option below, "As an exception..." unless there are more than 5 units on the project, or the units are going to a severe or hard to reach environment / strategic location. When choosing the second option instead of the first, coordinate with the Activity to determine the number of "production units" that must be tested.

The "As an exception..." sentence has always permitted the Special Factory Tests to be done on one of the first units produced, at the same time scheduled for the Routine Tests. However it was rarely used, since it only applies when the manufacturer already meets the experience requirements in the QUALIFICATIONS OF MANUFACTURER paragraph in Part 1 of this specification, but was building a slightly different unit without the specific design tests already on file.

With the new change to "kW vs kVA" requirements, this exception may become more frequently used since test data indicating the kW ratings specifically, may not be on file. The manufacturer still has to meet the QUALIFICATIONS OF MANUFACTURER paragraph,

and all of the Special Factory Tests will still be subject to being witnessed by the government with the Routine tests.

****

[As an exception, when the manufacturer does not have the special factory tests for the specific unit characteristics already on file, the manufacturer may conduct the special factory tests on the first "production unit" along with the routine tests.][The manufacturer must test [one] [_____] unit[s] at the same time scheduled for routine tests, of each rating and size converter.]To assure compliance with the specification, these tests are also subject to government witnessing at the same time as the routine tests. For all tests which require full load, use 1.0 power factor unless otherwise noted. For all tests that are "not already on file", connect loads to the converter with an aircraft power cable assembly, 32 meters 105 feet long, similar to the specified project aircraft power cable assembly. Monitor and record all data at the load end of the cable, unless otherwise noted. The tests conducted on the unit must include the following:

****

NOTE: Select Location Category C for outdoor locations only.

****

a. Initial Safety Verification: Perform tests and checks to validate the safe and timely shutdown for each condition (for the power source and the output cable) identified in paragraph SAFETY FUNCTIONS.

b. Surge protection: Apply input surges in accordance with IEEE C62.41.1 and IEEE C62.41.2, Location Category [B][C] and monitor output. Conduct a minimum of three consecutive successful tests on each unit listed. Confirm there is no interruption to 400 Hz output power and voltage stays within specified regulation tolerances. Surge protection tests must be applicable on all frequency converter units utilizing same surge protection device by manufacturer and part number regardless of frequency converter kW size.

c. Input current: Perform the following tests at nominal input voltage. Conduct each test a minimum of three times. Monitor the input and output power to demonstrate the duration of the transients until the converter reaches steady state. Provide copies of waveforms and analysis in test report.

(1) Measure inrush current when initially turning on machine with no load.

(2) After applying power and unit is at steady state, conduct load application test, going from 0 to full load to measure affect on input.

d. Input current distortion: Operate at nominal input voltage at 0, 25, 50, 75, and 100 percent of rated full load. Measure and record the input current THD for the current in each phase.

****

NOTE: For the Navy:

1) Include the bracketed 300 percent overload

requirement in the table. However, units strictly for avionics shop use do not need the 300 percent requirement.

2) Coordinate with NAVAIR (POC information is at front of specification), to see if the NAVAIR Digital File Information has been completed before including the bracketed documentation option. Include bracketed option once NAVAIR has established a defined version of Digital File Requirements (still in progress). Verify at that time if need to add requirement for both input and output waveforms / data on the 300 percent test.

****

e. Overload: Operate at nominal input voltage and output voltage with loads as listed below:

Percent of Full Load	Satisfactory Operating Time	Time Between Overloads	Iterations
110 percent	60 minutes	4 hours	3
125 percent	5 minutes	10 minutes	3
150 percent	2 minutes	10 minutes	3
200 percent	20 seconds	5 minutes	3
[300 percent	4 seconds	5 minutes	5]

Monitor output to confirm there is no 400 Hz power interruption. After minimum operating time is achieved, unit must interrupt output power. Provide voltage and current waveforms[in accordance with NAVAIR Digital File Information] documenting the unit's response for each test.

f. Short-circuit: Apply a bolted line-to-line fault and a bolted three phase fault directly to the output terminals of the unit. Conduct a minimum of three consecutive successful tests on each unit. Provide unit capable of carrying the fault current until the integral system protective devices interrupts the fault with no damage to the unit. Provide waveforms of short circuit current during short circuit tests.

g. Output voltage THD: Operate at nominal input voltage at full load with balanced and 15 percent unbalanced load. A 15 percent unbalanced load is defined as follows:

(1) Phase A at full rated single phase load.

(2) Phase B at 85 percent of Phase A

(3) Phase C at 85 percent of Phase A

Measure and record the output voltage THD for the line-to-neutral voltage of each phase.

h. Phase angle regulation: Operate at full load with balanced and 15 percent unbalanced loads. Measure and record output voltage and current, and identify RMS phase voltages and displacement angles between adjacent output voltage phases. A 15 percent unbalanced load is defined as follows:

(1) Phase A at full rated single phase load.

(2) Phase B at 85 percent of Phase A.

(3) Phase C at 85 percent of Phase A.

i. Transient recovery: Operate at the following load steps: 0 to 100 percent, 0 to 50 percent, 100 to 0 percent and 50 to 0 percent. Measure and record recovery time and output voltage deviation limits. Provide recordings or display of output voltage during transient recovery test.

****

NOTE: Delete bracketed acoustical noise test unless frequency converter is installed in special locations such as test laboratories or other confined spaces and a lower than 72 dBa value is specified.

The test parameters (Height and Range) identified below, meet the ANSI SI 4 requirements. However the standard is not referenced because it "allows units to be averaged over a certain production range /quantity", whereas we want each unit to be individually compliant.

****

[j. Acoustical noise: Operate at no load, 50 percent and 100 percent of full load. Measure continuous steady sound pressure level 1525 mm 5 feet horizontally from the center of each side of the converter at a point 1525 mm 5 feet above the floor. Decibels (dB) are referenced to 20 micropascal.

]

****

NOTE: Delete optional paralleling test unless paralleling requirement is specified with the equipment.

****

[k. Paralleling: Operate at nominal input voltage at 50 percent and 100 percent of full load at 0.8 lagging power factor. Measure and record the output voltage, output current and power factor provided by each individual unit.

l. Post Special Test Safety Verification: Repeat tests conducted under item a. Initial Safety Verification to confirm safety features were not affected by previous tests.

]2.7 ARC FLASH WARNING LABEL

****

NOTE: Include the Arc Flash Warning Label detail on the drawings. See the technical notes at the beginning of this section to obtain the AutoCAD drawing file of the label.

****

Provide arc flash warning labels for arc flash protection in accordance

with NFPA 70E and NEMA Z535.4 for the enclosures of electrical equipment that are likely to require examination, adjustment, servicing, or maintenance while energized. Locate this self-adhesive warning label on the outside of the equipment compartment doors warning of potential electrical arc flash hazards and appropriate PPE required. Provide label format as indicated. The marking must be clearly visible to everyone, including qualified persons, before examination, adjustment, servicing, or maintenance of the equipment.

2.8 FIELD FABRICATED NAMEPLATES

****
NOTE: Use the following paragraph where nameplates are fabricated to identify specific equipment designated on the drawings. Provide note on panelboard schedules to indicate where other than black center core labels are required.
****

ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified or as indicated on the drawings. Each nameplate inscription must identify the function and, when applicable, the position. Nameplates must be melamine plastic, 3 mm 0.125 inch thick, white with [black] [_____] center core. Surface must be matte finish. Corners must be square. Accurately align lettering and engrave into the core. Minimum size of nameplates must be 25 by 65 mm 1 by 2.5 inches. Lettering must be a minimum of 6.35 mm 0.25 inch high normal block style.

2.9 GROUNDING AND BONDING

****
NOTE: Include the reference to Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION when equipment is also being provided outside.
****

UL 467. Provide grounding and bonding as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM[and for exterior work, in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION].

[2.10 CAST-IN-PLACE CONCRETE

****
NOTE: Include concrete requirements when equipment is also being provided outside on concrete pads.
****

Provide concrete associated with electrical work for other than encasement of underground ducts rated for 30 MPa 4000 psi minimum 28-day compressive strength unless specified otherwise. Conform to the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

]PART 3 EXECUTION

3.1 INSTALLATION

Install products to operate at 400 Hz in the same manner as specified in other sections of this specification for products operating at [50] [60]

Hz, unless indicated or specified otherwise. Conform to the requirements of NFPA 70 and IEEE C2 and to manufacturer's instructions and recommendations.

3.2 EQUIPMENT

3.2.1 Floor Mounted

Provide proper floor mounting channels and install in accordance with the manufacturer's drawings and instructions and as indicated. Align, level, and bolt units to channels to allow easy withdrawal or insertion of removable components and to permit proper operation and maintenance of equipment. When in a Class 1, Division 2 area, mount units at least 18 inches above finished floor.

[3.2.2 Wall Mounted

****
NOTE: Wall mount units 5 kW or less. Floor mount all other units.
****

Bracket mount, but otherwise install as required for floor-mounted units.

][3.2.3 Maintenance Platform Mounted

****
NOTE: When used, verify drawings identify:

1) An appropriate maintenance platform with safety details including the maintenance envelope.

2) The location of the remote control panel and interconnecting conduit and wiring.
****

Install as required for floor-mounted units.

]3.2.4 Grounding and Bonding

In accordance with NFPA 70 and as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

[3.2.5 Grounding and Bonding - Exterior Equipment

****
NOTE: When equipment in the project is located outdoors, include the optional grounding and foundation (concrete pad) requirements. Use 25 ohms unless the project requires more stringent requirements.
****

NFPA 70 and IEEE C2, except provide grounding systems with a resistance to solid earth ground not exceeding [25][_____] ohms.

3.2.5.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND

ELECTRICAL DISTRIBUTION.

3.2.5.2 Pad-Mounted Equipment Grounding

****

NOTE: Ensure plans show the pad details and ground connections matching how this paragraph is edited. Converter is to have a ground ring and the normal number of ground rods is two. The one ground rod option should only be chosen if required by local installation requirements.

****

Provide a ground ring around the equipment pad with 4/0 AWG bare copper.[Provide two ground rods in the ground ring at opposite corners.][Provide one ground rod in the ground ring with the ground rod located in the equipment cabinet.] Install the ground rods at least 3000 mm 10 feet apart from each other. Provide separate copper grounding conductors and connect them to the ground loop as indicated. When work in addition to that indicated or specified is required to obtain the specified ground resistance, the provision of the contract covering "Changes" applies.

3.2.5.3 Connections

Connect ground conductors to the upper end of ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors. Make joints in grounding conductors and loops by exothermic weld or compression connector. Install exothermic welds and compression connectors as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

3.2.6 Foundation for Equipment and Assemblies

****

NOTE: Mounting slab connections may have to be given in detail depending on the requirements for the seismic zone in which the requirement is located. Include construction requirements for concrete slab only if slab is not detailed on drawings.

****

Mount equipment on concrete slab as follows:

a. Unless otherwise indicated, provide the slab with dimensions at least 200 mm 8 inches thick, reinforced with a 152 by 152 mm MW19 by MW19 6 by 6 inches - W2.9 by W2.9 mesh placed uniformly 100 mm 4 inches from the top of the slab.

b. Place slab on a 150 mm 6 inch thick, well-compacted gravel base.

c. Install slab such that top of concrete slab is approximately 100 mm 4 inches above the finished grade with gradual slope for drainage.

d. Provide edges above grade with 15 mm 1/2 inch chamfer.

e. Provide slab of adequate size to project at least 200 mm 8 inches beyond the equipment.

Stub up conduits, with bushings, 50 mm 2 inches into cable wells in the concrete pad. Coordinate dimensions of cable wells with equipment cable training areas.

3.2.6.1 Cast-In-Place Concrete

Provide cast-in-place concrete work in accordance with the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

[3.2.6.2 Sealing

****
NOTE: Require sealing of cable wells (windows) in the concrete pad if rodent intrusion is a problem.
****

When the installation is complete, seal all entries into the equipment enclosure with an approved sealing method. Provide seals of sufficient strength and durability to protect all energized live parts of the equipment from rodents, insects, or other foreign matter.

]]3.2.7 Wiring and Conduit

****
NOTE: Designers of Record must provide calculations and derate conductors, circuit breakers (50 Hz / 60 Hz), and devices operating at 400 Hz and at 28 VDC. Do not use ferrous (steel) conduit for 400 Hz wiring.

Use of a distributed 400 Hz power system (instead of a Point of Use system), is prohibited on new projects, and is limited to making modifications to existing systems. If used, a distributed system requires additional special calculations to accommodate for unbalance in the system, which may also require the use of the bracketed option for the special 7-conductor, 6 around 1 cable in conduit.

See UFC 3-555-01 (Draft in progress) for additional information.

Circuit Breakers	
	Derating Factor
QO (< 50 A)	0.927
H, J, & L Frame (,400 A)	0.8 to .9
J Frame (600 A)	0.82
K Frame (1200 A)	0.74

Cable	
AWG	Derating Factor
#2	0.9877

Cable	
AWG	Derating Factor
#1	0.9675
#1/0	0.9481
#2/1	0.9167
#3/0	0.8831
#4/0	0.8483

****

Provide wiring and conduit as specified in Section 26 20 00, INTERIOR DISTRIBUTION SYSTEM. Use copper conductors [type XHHW, 7-conductor, 6 around 1, twisted] for 400 Hz systems. Use aluminum conduit for exposed 400 Hz feeders. Do not install aluminum conduit underground or encased in concrete. Use aluminum fittings and boxes with aluminum conduit. Use PVC conduit and fittings for underground or concrete encased 400 Hz feeders.

3.2.8 Manufacturer's Representative

The manufacturer's representative must place the system in operation and make necessary adjustments to ensure optimum operation of the equipment. The manufacturer's representative must have at least 2 years of practical experience in the installation and testing of 400 Hz solid state frequency converters.

3.3 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.4 WARNING SIGN MOUNTING

Provide the number of signs required to be readable from each accessible side. Space the signs in accordance with NFPA 70E.

3.5 FIELD APPLIED PAINTING

Where field painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance to manufacturer's instructions.

3.6 FIELD QUALITY CONTROL

3.6.1 Field Test Schedule

****

NOTE: Include the bracketed options below on Navy projects where "reach-back support" has already been coordinated with NAVAIR / NAVFAC LANT per the third introductory Technical Note at the beginning of this specification section.

****

Give Contracting Officer[and (NAWCAD Air Vehicle Electrical Power Systems Group (AB43) (301) 342-4161] 30 days notice of dates, times and scheduled tests which require the presence of the Contracting Officer. The Contracting Officer will coordinate with the using activity[and NAVAIR / NAVFAC LANT,] and schedule a time that will eliminate or minimize interruptions and interference with the activity operations.

3.6.2 Instruments

Provide test instruments capable of measuring and recording or displaying test data at a higher resolution and greater accuracy than specified for the converter's performance. The test instruments used in the field tests must have current valid calibration stickers issued by an approved calibration laboratory. Verify calibration and adjustments of converter instruments provided prior to field tests. Calibrate instruments for 400 Hz operation when measuring 400 Hz signals.

3.6.3 Initial Inspection and Tests

****

NOTE: Include the bracketed option for the NETA ATS Representative when Section 26 08 00 APPARATUS INSPECTION AND TESTING is included in the project. Ensure that the list of identified specification sections that the NETA inspector is responsible for includes this section (see bracketed options in Section 26 08 00 APPARATUS INSPECTION AND TESTING).

****

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests.[In addition, coordinate with the NETA ATS representative to witness, document, and validate the converter Field Quality Control.]

a. Compare equipment nameplate information with specifications and approved shop drawings.

b. Inspect physical and mechanical condition. Inspect cables and wiring harnesses for damage and strain relief.

c. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey. Perform thermographic survey while the unit is at full load during the loadbank test.

d. Perform specific inspections and mechanical tests as recommended by manufacturer.

e. Verify correct equipment grounding.

3.6.4 Field Performance Checks and Tests

****

NOTE: For the Navy, designers must coordinate with the Activity during the initial design phase. If the Activity has a reactive load bank on base that can be used during the field testing phase of the

project, then:

1) Include the bracketed option to utilize the base equipment and perform the additional reactive load tests in the field.

2) Descriptions of the existing Activity owned loadbank, as well as information on where and how to obtain it, who is responsible to run it, and who has the liability for it, must also be included in the project documents, in Section 01 11 00 SUMMARY OF WORK.

****

Conduct converter field checks and tests under the supervision of the manufacturer's representative. Provide labor, equipment, test instruments, and incidentals required for the tests including resistive load banks, except the Government will furnish the electricity. For all electrical load tests, use 1.0 power factor unless otherwise noted.[As an additional exception, utilize the Government furnished reactive load bank as specified in Section 01 11 00 SUMMARY OF WORK, under paragraph, GOVERNMENT FURNISHED EQUIPMENT, and additionally repeat the routine factory tests that address lagging and leading power factors, in the field.]

All tests must be performed with the load connected to the load end of the specified aircraft cable assembly. The cable must be laid out / uncoiled to provide heat dissipation. No adjustment to the converter is allowed between tests. Successfully complete the safety verification, preliminary operation, and the control and protective devices check prior to performing load and transient tests. Load tests must be performed with the converter doors closed. If the converter fails to operate within the specified limits during any of the tests, discontinue the test, make necessary repairs to correct the failure, and restart testing of the converter. Repeat all previously completed tests and document the respective failed test data and new data.

3.6.4.1 Initial Safety Verification

Perform tests and checks to validate the safe and timely shutdown for each condition (for the power source and the output cable) identified in paragraph SAFETY FUNCTIONS. As an exception, a representative fault test will be sufficient at this time.

3.6.4.2 Preliminary Operation

****

For the Navy: NAVAIR is working on and will provide the requirements for a "digital manual" / type of "Data Acquisition system." All Manufacturers should also already have one of their own. The future goal is to include the standardized requirement as part of the specification so that NAVAIR will have the various manufacturer's equipment information, in a consistent format, submitted and then on file in the NAVAIR Database system for maintenance and problem solving. At that time, we will determine whether it will be possible to include as an attachment / sample in the specification or possibly as a

reference to a UFC Appendix.
****

Inspect the converter and make adjustments necessary to assure proper operation in accordance with the manufacturer's instructions. Operate converter at 0, 25, 50, 75, and 100 percent of rated full load. On both the input and the output, measure and record the voltage, current, frequency, and THDs (voltage and current) at each load. Calculate output voltage regulation. Verify converter is operating within specified limits at each load level.

Test data must include voltage and current harmonic distortion amplitudes of all individual harmonics presented in a spectrum analysis format up to the 15th order at the 50 percent and 100 percent load points.

3.6.4.3 Control and Protective Device Checks

Operate each control, switch, input/output device that is capable of being operated manually a minimum of three times, demonstrating satisfactory operation each time. Perform operation test on each protective device to ensure that devices function properly. After each operation measure and record the converter output frequency, voltage and current. Verify converter is operating within specified limits.

3.6.4.4 Load (Burn-in) Test

****
NOTE: Include the bracketed option "For converters used ..." only when one of the frequency converters, on a multi converter project, will not be connected to the aircraft cable assembly when in service; e.g. used in a lab setting instead.

In the rare condition, where there is only the one converter in a lab setting, then delete the entire sentence before the bracketed option as well.
****

Operate each unit continuously a minimum of 1 hour at 100 percent rated full load. Measure and record the converter output frequency, voltage and current at beginning, 30 minutes, and 1 hour. Verify converter is operating within specified limits. Load test must be performed with the converter doors closed and the test load connected to the converter at the cable head with specified aircraft cable assembly.[For converters used to supply test bench loads, perform load tests with the converter doors closed at the output of the converter.]

3.6.4.5 Post Load Test Verification

Repeat tests identified in paragraph PRELIMINARY OPERATION, to validate converter was not affected by the Load test. However apply loads in the reverse order (e.g. 100, 75, 50, 25, and 0 percent of the rated full load).

Conduct tests on each converter with the load connected to the load end of the specified aircraft power cable assembly. No adjustment to the converter is allowed between load tests. Monitor and record output voltage at the load end of the cable. Verify specified performance of the converter including the line drop compensation.

3.6.4.6 Final Safety Verification

Repeat tests conducted under paragraph INITIAL SAFETY VERIFICATION to confirm safety features were not affected by previous tests.

3.6.5 Grounding System

Inspect grounding system for compliance with contract plans and specifications.

3.7 DEMONSTRATION

3.7.1 Instructing Government Personnel

****

NOTE: For Navy: Include bracketed option requiring coordination with NAVAIR and coordination with Activity on availability of aircraft for conducting training.

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Provide field training to Government personnel on the operation and maintenance of the converter provided at the same time as the Field Acceptance Testing.[For Navy projects contact NAWCAD Air Vehicle Electrical Power Systems Group (AB43) at (301) 342-4161 to obtain the name and e-mail of the NAVAIR point-of-contact so they can attend the training. Coordinate with the Activity to establish availability and non-availability to train on actual aircraft.] Include up to a maximum of 2 hours of instruction on operation and up to a maximum of 4 hours of repair and maintenance of the converters. The instructor must be approved by the manufacturer of the unit provided. Submit training syllabus including each topic of training and a brief outline of each topic to the Contracting Officer at least 4 weeks prior to training for approval.

Training must be approved by the Contracting Officer at least 2 weeks in advance. The Government may record, video and audio, the training sessions and use these recordings to train personnel on the operation and maintenance of the converter system. Provide two copies of video or audio DVDs, and of any supplemental information and examples covered in the training sessions, to the Contracting Officer.

-- End of Section --