PREFACE

PURPOSE OF THIS DOCUMENT

The intent of this document is to disseminate the San Francisco International Airport’s (SFO’s or Airport’s) expectations regarding the information presented to designers, engineers, general contractors and other industry specialists. The material provided in the following sections includes the minimal requirements, general information, design criteria, guide specifications and details for electrical work installed at SFO. While this document addresses major areas of concern to SFO, it is not an all-inclusive document.

HOW TO USE THIS DOCUMENT

This document should be used as a resource for the development of project specific design documents including drawings, details and specifications. It is the responsibility of the design, engineering and construction professionals to adhere to all codes and regulations related to the content presented.

SCOPE

This section contains the Standards and Criteria for Electrical: 400 Hertz (Hz). Any questions or concerns regarding the items or equals specified must be submitted to the Standards Committee in writing. All final decisions regarding products shall be made at the Airport’s discretion. If the Engineer of Record presents items that are not specified or named equals, they must be brought to the Standards Committee for evaluation of those products.

DRAWING REQUIREMENTS

A. All design disciplines including the architectural/engineering sub-consultants and the trade bid package subcontractors shall prepare documents using Revit in the current version utilized by the Airport in compliance with the Airport’s Building Information Modeling (BIM) Requirements as described in Document 00 73 87: BIM Requirements, unless waived by the Chief Development Officer.

B. When Revit models may not be applicable, (for example, tasks with underground infrastructure beyond a building footprint), Civil 3D may be used to model utilities and applicable infrastructure if approved by the Chief Development Officer.

C. Refer to technical specifications for As-Built requirements.

D. Documents and plans submitted to SFO shall be searchable using PDFs with live text. This includes, but is not limited to, text and symbols. The document shall also provide the capability to turn layers on and off. Any project using legacy documents which may be composed image files shall be converted to live text via Optical Character Recognition (OCR).
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PART 1 – GENERAL

1.1 SUMMARY

A. In general, depending on the specified equipment size, the 90 KVA or 180 KVA gate box assembly shall be a stand-alone device to provide transformation of 400 Hz, 575 VAC to 118/204 VAC with 115/200 VAC available tap, for aircraft use. The gate box shall be supplied with an integral line drop compensator section. The gate box assembly shall be labeled per UL 508.

1.2 References

A. The publications listed below form a part of this specification to the extent referenced and applicable. Latest versions of the publications shall be used. The publications are referred to in the text by the basic designation only.
   2. National Fire Protection Association (NFPA) 70
   3. National Electrical Code (NEC)
   4. Underwriters Laboratories (UL) 508- Industrial Control Equipment
   5. National Electrical Manufacturers Association (NEMA)

1.3 FACTORY TESTING

A. Certified evidence shall be submitted that the gate box manufacturer has made factory tests on each gate box. Tests shall include no-load, 54 KVAR, 72KW and full load test at 90 KVA, 0.8 pf. Copies of the test data shall be submitted to the Engineer for review and approval.

1. Tests results shall be submitted prior to shipment of the equipment and shall be conducted in accordance with requirements of the specifications pertaining to 400 Hertz Testing, Adjusting and Balancing, MIL-STD-704E and NFPA. If a conflict exists between this specification and referenced Standards, the most stringent or current Airport requirements shall be utilized as acceptable test results. At no additional cost, the owner representative reserves the right to send 2 or more personnel to witness the Factory Acceptance Test.

B. Acceptable load test results shall be:

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<th>Load</th>
<th>Line to Neutral Voltage</th>
<th>Amperes</th>
</tr>
</thead>
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<tr>
<td>No load</td>
<td>118 ± 0.5V (115 ± 0.5V, at tap)</td>
<td>0</td>
</tr>
<tr>
<td>54 KVAR</td>
<td>118 ± 1V</td>
<td>156 ± 5A</td>
</tr>
<tr>
<td>72KW</td>
<td>113 ± 1V</td>
<td>208 ± 5A</td>
</tr>
<tr>
<td>90 KVA @0.8PF</td>
<td>115 ± 0.5V (115 ± 0.5V, at tap)</td>
<td>260 ± 5A</td>
</tr>
</tbody>
</table>

C. Reported factory test results shall be field verified and tested under 400 Hertz Testing, Adjusting and Balancing, as specified herein. Any deviations from the specified line to neutral voltage range under given load conditions shall not be allowed and the gate box shall be rejected and replaced with similar gate box or approved equal, at manufacturer’s expense.
1.4 SAFETY

A. Capacitor isolated neutral ensures that power distribution prevents sparking from alternate ground(s) i.e., static ground. Gate Box shall be of the “Dead Front Panel” construction and lockable.

1.5 TRAINING

A. Contractor shall provide a trained manufacturer’s representative to perform on-site maintenance training for up to 15 Airport staff at no additional cost to the Airport. Training shall be performed for a minimum 24 hours, completed as three, 8-hour days. The Contractor is responsible for scheduling the training and shall do so at a time agreeable with Airport staff. Training agenda and written training manual shall be submitted to the Airport for review and approval, 3 weeks prior to the start of actual training.

PART 2 – PRODUCTS

2.1 90KVA or 180 KVA GATEBOX WITH LDC

A. Approved Manufacturers:
   1. MCM Engineering
   2. Or approved equal

2.2 ENCLOSURE

A. The gate box cabinet shall be welded #11-gauge steel with stainless steel door piano hinge. The finish shall be 2 coats of primer and one coat of polyurethane paint. The color to be as specified by the customer. The top shall be removable to facilitate complete paint coverage. The unit shall be NEMA 3R compliant.

B. The enclosure top cover shall have threaded connections for lifting eyes.

C. Storage receptacle for spare bulbs and fuses shall be located on the interior of the gate box door.

D. The gate box shall be supplied with supports and brackets for installation to the loading bridge. The supports shall be fabricated in such a manner as to accommodate the attachment of the gate box by bolts. The color and finish shall match the gate box.

2.3 TRANSFORMER

A. Depending on the size selected, the gate box shall contain one 90 kVA or 180 kVA, 400 Hz dry type step down isolation transformer with 575V delta connected primary and wye connected secondary of 118/204V with 115/200V tap included.

B. Insulation shall be class “H” varnish impregnation, two coats as called for under MIL-I-24092.

C. The minimum B.I.L. shall be 10,000 volts.

D. The voltage regulation of the line to neutral, no load to full load shall be 0.6% at unity power factor and 1.5% at 0.8 lagging power factor.

E. The transformer shall have the selected (90 or 180) full KVA continuous duty rating.
2.4 LINE DROP COMPENSATOR (LDC)

A. The Line Drop Compensator is used to eliminate the reactive voltage losses (line drop) in long runs of 400 Hz power distribution. The gate box shall have one or two compensators, one for each output circuit depending on the KVA size selected. Each compensator shall be rated at 90- KVA, 200-volt, 3-phase, 400 Hz continuous load at 0.8 power factor. The compensator shall be capable of correcting an inductive impedance from 6-16% and shall be step adjustable with a minimum of 6 steps.

B. Each compensator shall contain three 400 Hz dry type current transformers, one for each phase (A, B and C). Maximum rating of each transformer shall be 260 amps. Insulation shall be class “H” varnish impregnation, two coats as called for under MIL-I-24092. The transformers shall have multiple taps on the secondary winding for adjustment of the reactive compensation for various combinations of cable lengths and sizes to provide voltage boost from 6% to 16% in 2% increments. The secondary taps shall be positioned in an accessible location to allow adjustment without reaching over or around the primary taps in order to reduce the possibility of coming into contact with the 118/204 or 115/200 volt power, whichever is used. The taps shall be of the quick connect terminal type. A decal shall show the boost connections. The transformers shall have a 90-amp continuous duty rating. The temperature rise of magnetic components shall not exceed 80 °C over a 40 °C ambient under rated load conditions.

C. A total of six 34 µfd capacitors are used in each compensator. Two capacitors will be connected in parallel across the secondary windings of each transformer to reflect capacitive reactance into the main transmission line and cancel the inductive reactance. Capacitors shall be non-PCB type.

D. All compensator components shall be factory wired to be an integral part of the gate box.

E. Capacitor voltage rating to be such that if one capacitor fails, the second will withstand the increase in voltage and current. The compensator shall handle a 250% load transient without interruption of service or system degradation.

F. Provide line drop compensation, as determined from the voltage drop calculations, to ensure compliance with MIL-STD-704E to furnish the correct voltage at the aircraft cable plug.

2.5 CONTACTOR

A. Provide two 600V, 325 Amp, 400 Hz rated load contactor. The contactor will be provided with lugs capable of landing up to one #4/0 or two #2/0 wires per phase. The coil shall be 100 VDC.

2.6 CONTROLS AND INDICATORS

A. A 600V, 3-pole, 250 amp manually operated disconnect isolation switch shall be provided on the fixed portion of the enclosure and shall be lockable with internal and external override.

B. The gate box assembly shall be equipped with individual industry standard PC boards, factory adjusted, to provide over voltage, under voltage and overload protection in accordance with MIL-STD-704E. Contract shall furnish one additional complete set of spare PC boards for each 400 Hz gate box.

C. E/F feedback circuit shall use relay logic to insure proper aircraft interlock and safety. This circuit shall also be equipped with an MOV to eliminate any 400 Hz induced voltage from the single jacketed aircraft cable.
D. 12-volt cluster LED, minimum 100,000 hours, indicating lights and illuminated pushbuttons shall be located on the exterior of the gate box cabinet. Buttons and lights shall be 30 mm diameter. Buttons and lights shall be provided as follows:

1. Power Available Light - power is available in the gate box.
2. Overload Light - An overload fault has occurred.
3. Under Voltage Light - An under-voltage fault has occurred.
4. Over Voltage Light - An over voltage fault has occurred.
5. Reset Button - Resets the assembly after a fault has occurred.
6. Test Button - Illuminates all lamps.

E. All lights, local and remote pushbutton, and controls, shall be 12 VDC with a continuous duty 5-amp power supply.

F. Spare bulbs and fuses of each type shall be provided.

G. Remote indication shall be provided by the use of signaling relays. Relay contacts will indicate when:

1. Power Available: 400 Hz power is available in the gate box
2. Contactor Closed: The E & F circuit is energized, indicating that power is being supplied to the aircraft. Individual signal for each of two contactors.
3. Fault Summary: A fault has occurred (overvoltage, under voltage or overload) and the gate box is inoperable until the fault is cleared and the control circuit reset.

2.7 GATE BOX TEST PANEL

A. The gate box shall contain a silk screened schematic and component legend on a sixteen-point test panel for troubleshooting the following conditions:

1. Output voltage of each of the three phases.
2. Output voltage of the DC power supply.
3. Contactor auxiliary contacts.
5. Under voltage relay contacts.
6. Over voltage relay contacts.
7. Overload relay contacts.
8. Overload relay.
10. Test switches to facilitate testing and troubleshooting:
11. E/F bypass switch for test purposes when 28 VDC power is not available.
12. Contactor disable switch to disable the gate box output, but still leave input power to the box enabled.
13. A “Back Feed” receptacle, to allow 400 Hz external power for purposes of testing normal gate box operation, over voltage and under voltage protection, shall be provided on the face of the test panel.

2.8 SUBMITTALS

1. Single Submittal: One (1) hard copy and one (1) electronic copy is required for all products
covered by this Section.

PART 3 – EXECUTION

3.1 NORMAL OPERATION

A. Power from the Gate Box to the aircraft is delivered through an aircraft cable and controlled by push buttons on the gate box front or by push buttons in the cable head. 400 Hz pushbuttons include “ON,” “OFF,” “RAISE,” and “LOWER” in both locations.

B. To provide 400 Hz power to an aircraft, insert the aircraft cable into the aircraft receptacle. Check to be certain that the plug has been fully inserted. Check to see that the Power Available light is ON. Press the ON push button. The CONTACTOR CLOSE light will be ON indicating that the load contactor is closed and that power is available to the aircraft. With a dual output gate box, care must be taken to correctly identify which aircraft cable is associated with the proper pushbutton.

C. NOTE: If an overload or under/under voltage fault should occur, the load contactor will drop out and the RESET button will have to be pushed to turn the fault light OFF. Determine the cause of the fault before applying power to the aircraft again.

D. To terminate power use, press the OFF push button. The CONTACTOR CLOSED light will go out, indicating that the load contactor has opened and that power is no longer flowing to the aircraft. The aircraft cable can now safely be removed from the aircraft.

3.2 Load Contactor Automatic Opening

A. The load contactor shall open automatically under the following conditions.
   1. Over Voltage to meet the parameters of MIL-STD-704E.
   2. Under Voltage to meet the parameters of MIL-STD-704E.
   3. Overload
      a. After 5 minutes at 125% of full load.
      b. After 30 seconds at 150% of full load.
      c. After 0.6 seconds at 200% of full load.

END OF SECTION 22 99 00
SECTION 26 99 01 – 400 Hz AIRCRAFT GROUND POWER CABLE

PART 1 – GENERAL

1.1 SUMMARY

A. The 400 Hz Aircraft Cable shall be of the single jacketed type suitable for nominal 115/200 volt, 3-phase, 4-wire, 400-Hz power. The cable shall meet MIL-C-5756 and the cable connector assembly MIL-C-7974. Cable shall consist of six power conductors twisted around a single neutral conductor. Eighteen control wires, six groups of three wires, are included in the cable bundle.

1.2 DESCRIPTION OF WORK

A. The Contractor shall furnish and install ground power cables as indicated in the Contract Documents.

B. Electrical wiring, including power, controls, and data shall be specified.

1.3 REFERENCE STANDARDS

A. The latest versions of publications listed below form a part of this specification to the extent referenced and applicable. The publications are referred to in the text by the basic designation only.

1. Military Standards MIL-C-5756: General Specification for Cable, Power, Electrical, Portable
3. National Fire Protection Association (NFPA) 70
4. National Electrical Code (NEC)
5. Underwriters Laboratories (UL) or ETL Listings

1.4 SUBMITTALS

A. Catalog cut sheets shall include specifications, installation instructions, and general requirements for type of cable required.

B. Single Submittal: One (1) hard copy and one (1) electronic copy is required for all products covered by this Section.

PART 2 – PRODUCTS

2.1 CABLE MANUFACTURER

A. Aircraft Ground Power Cable assembly shall be the same manufacturer of the 400 Hertz Gate box, Specification Section 26 99 00 - 400 Hertz Gate Box with LDC.

1. J&B Aviation
2. Or approved equal.

2.2 400 HERTZ CABLE WITH AIRCRAFT POWER PLUG

A. Cables shall be single jacket type, length as indicated on Drawings suitable for nominal 115/200 Volt, 3-Phase, 4-Wire, 400 Hertz power. Cables shall be marked as required in Article 400-6 in compliance with regulations.
with the requirements of Article 300-11 which requires maximum rated voltage for which the conductor was listed, type of rating on insulation, the manufacturer’s name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified, and the AWG size or circular-mil area. The conductors shall be color coded to meet the requirements of Articles 400-22 and 400-23 of the NEC. Components shall be as follows:

1. Power Conductors: 6-#4 AWG (21 mm²) Class M stranding
2. Neutral Conductor: 6-#10 AWG or 1-#1 AWG Class M stranding
3. Control Conductors: Minimum of 12-#18 AWG (0.82 mm²) Class M stranding
4. Outer Jacket: Pressure extruded rayon-reinforced black neoprene 0.17: (0.43 cm) nominal wall
5. Bend Radius Minimum: 10” (25.4 cm)
6. Temperature Range: 67 °F to +130 °F (-55 °C to +55 °C)
7. Storage Temperature Range: 67 °F to +150 °F (-55 °C to +65 °C)
8. Humidity: 0 to 100%
10. Diameter: 1.65” (4.19 cm)
11. Weight Per Foot: 2 lbs. (0.9 kg)
12. Voltage Rating: 600 VAC
13. Ampacity: 260 amperes
14. Frequency: 400 Hertz
15. Voltage Drop: 2.99 Volts (Measured at 90 KVA, 0.8 power factor on 60’ cable)
16. Voltage Unbalance: 0.20 Volts (Measured at 90 KVA, 0.8 power factor on 60’ cable)
17. Resistance: 0.157 Ohms per 1000’
18. Inductance: 0.0000410 Henries per 1000’

B. Plug Section

1. Shall include 400 Hertz ON pushbuttons and cable hoist UP/DOWN pushbuttons, easily changed or replaced in the field in 3-5 minutes that uses silver-coated copper. Each individual power plug shall have a threaded base for field replacement.
2. Shall have a high visibility replacement contact section (nose), which allows for infield replacement in 3-5 minutes. Aircraft cable connector shall be a molded material conforming to MIL-C-7974. It shall be attached to the aircraft cable with a conical stain relief that is part of the molded connector. The connector shall have a field replaceable nose section.
3. Molded tapered strain relief release at connector back. This release is required to accommodate the whipsaw action commonly used when inserting and removing connectors from aircraft.
4. Plug shall be green in color.

C. Aircraft cable assembly shall be UL-listed and labeled.

D. Terminal Lugs: The wires shall have terminal lugs that are made for stud connection. A, B & C lugs shall be for 3/8” studs. The N, E & F lugs shall be 5/16” and the other control wires shall be for a #10 stud.

E. Cable shall be protected with a scuff guard that is orange over black in color, abrasion and crush resistant, and have a length equal to the length of the overall cable minus 5’.

F. Cable head shall contain “OFF,” “UP,” “DOWN,” only pushbuttons.

G. Cable Length: 80’ or 100’

PART 3 – EXECUTION
3.1 INSTALLATION
   A. Contractor shall install cable according to Manufacturer's instructions.
   B. Installation shall be coordinated to prevent the cable from lying on the ramp after installation susceptible to damage by construction traffic.

3.2 TESTING
   A. Prior to energizing, test conductors of cable for electrical continuity and for short circuits.
   B. Cables shall be energized prior to final acceptance to demonstrate proper functioning. Contractor shall replace defective cables, correct wiring errors and retest to demonstrate compliance.

3.3 FIELD QUALITY CONTROL
   A. Division 1 sections pertaining to Quality Control and Contract Closeout.

END OF SECTION 26 99 01
SECTION 26 99 02 – 400 Hz TWISTED CABLE

PART 1 – GENERAL

1.1 SUMMARY
A. 400 Hz twisted cables shall be twisted by the manufacturer experienced in the twisting of 400 Hz cables. Conductors shall consist of stranded, bare, soft drawn copper, insulated with cross-linked polyethylene, type XHHW-2.

B. Related Section: Low Electrical Power Conductors and Cables – 26 05 19

1.2 DESCRIPTION OF WORK
A. Furnish and install 400 Hz twisted cables as indicated in the Contract drawings.

B. Electrical wiring, including power, controls, and data are specified in Division 26.

1.3 REFERENCE STANDARDS
A. Electrical wiring, including power, controls, and data are specified in Division 26.

B. The latest versions of publications listed below form a part of this specification to the extent referenced and applicable. The publications are referred to in the text by the basic designation only.
   1. Military Standards MIL-C-5756: General Specification for Cable, Power, Electrical, Portable
   3. National Fire Protection Association (NFPA) 70
   4. National Electrical Code (NEC)

1.4 SUBMITTALS
A. Submit catalog cut sheets of product data in accordance with Division 01 - Submittals of these Specifications. Catalog cut sheets shall include specifications, installation instructions, and general requirements for type of cable required.

1.5 FEATURES
A. Phase to phase imbalance is kept to a minimum by the balanced geometric construction.

B. Twisted cable allow for a single, easy, conduit pull.

PART 2 – PRODUCTS

2.1 MANUFACTURERS
A. Service Wire Co.
B. Or approved equal

2.2 STANDARDS
2.3 CABLES

A. Cable shall be marked as required in NEC Article 400 in compliance with the requirements of Article 300 which requires maximum rated voltage for which the conductor was listed, type of rating on insulation, the manufacturer’s name, trademark, or other distinctive marking by which the organization responsible for the product can be readily identified, and the AWG size or circular-mil area. The conductors shall be color coded to meet the requirements of Articles 400 and 400 of the NEC. Cable features shall be as follow:

1. 3#250 KCMIL Twisted Cable:

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<th>Feature</th>
<th>Specification</th>
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<tr>
<td>Cross-Sectional Area</td>
<td>1.81 Square Inch</td>
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<tr>
<td>Overall Diameter</td>
<td>1.52”</td>
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<tr>
<td>Minimum Bending Radius</td>
<td>8.0”</td>
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<tr>
<td>Maximum AC Resistance (90c)</td>
<td>0.0542 Ω/1000’</td>
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<tr>
<td>Inductive Reactance (25c)</td>
<td>0.1766 Ω/1000’</td>
</tr>
<tr>
<td>Nominal Weight</td>
<td>2589 pounds/1000’</td>
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<tr>
<td>Maximum Pulling Tension</td>
<td>6000 pounds (For straight pull)</td>
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<tr>
<td>Maximum Sidewall Pressure</td>
<td>500 pounds/foot-radius</td>
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<tr>
<td>Ampacity</td>
<td>374 Amps</td>
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<tr>
<td>Insulation Thickness</td>
<td>65 Mils</td>
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<td>Cable Capacitance</td>
<td>252.49 pico farad/foot</td>
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2. 3#3/0 AWG Twisted Cable

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<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Cross-Sectional Area</td>
<td>1.17 Square Inch</td>
</tr>
<tr>
<td>Overall Diameter</td>
<td>1.22”</td>
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<tr>
<td>Minimum Bending Radius</td>
<td>6.4”</td>
</tr>
<tr>
<td>Maximum AC Resistance (90c)</td>
<td>0.0806 Ω/1000’</td>
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<tr>
<td>Inductive Reactance (25c)</td>
<td>0.1787 Ω/1000’</td>
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<tr>
<td>Nominal Weight</td>
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<td>Maximum Pulling Tension</td>
<td>4027 pounds (For straight pull)</td>
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<td>Maximum Sidewall Pressure</td>
<td>500 pounds/foot-radius</td>
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<td>Ampacity</td>
<td>287 Amps</td>
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<tr>
<td>Insulation Thickness</td>
<td>55 Mils</td>
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<tr>
<td>Cable Capacitance</td>
<td>236.37 pico farad/foot</td>
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PART 3 – EXECUTION

3.1 INSTALLATION

A. Contractor shall install cable according to Manufacturer’s recommendations.

B. Installation shall be coordinated to prevent the cable from lying on the ramp after installation susceptible to damage by construction traffic.
3.2 TESTING

A. Prior to energizing, test conductors of cable for electrical continuity and for short circuits.

B. Cables shall be energized prior to final acceptance to demonstrate proper functioning. Contractor shall replace defective cables, correct wiring errors and retest to demonstrate compliance.

END OF SECTION 26 99 02
SECTION 26 99 03 – 400 Hz ELECTRICAL PIT SINGLE OUTPUT

PART 1 – GENERAL

1.1 DESCRIPTION

A. Furnish a prefabricated 400 Hz, single output ground power electrical service pit assembly. This prefabricated pit assembly shall come complete with all internal components including explosion-proof junction boxes, aircraft cables with plug assemblies, cable roller guides, conduit seal offs and couplings that project through the pit wall for connection of incoming conduit. Pit shall be comprised of a fiberglass shell with a removable cast aluminum cover.

1.2 QUALIFICATIONS

A. The manufacturer of the pit and cover shall submit proof of prior experience in the manufacturer of cast aluminum covers, fiberglass pits and airfield application of the fabricated pit assembly.

1.3 REFERENCES

A. The latest editions of the publications listed below form a part of this specification to the extent referenced and applicable. The publications are referred to in the text by the basic designation only.

2. National Electrical Code (NEC)
3. National Electrical Manufacturers Association (NEMA) 7D – Enclosure for use in Class 1, Division 1, Group D Environment
4. Underwriters Laboratories (UL) 886 – Outlet Boxes and Fittings for Use in Hazardous Locations

PART 2 – PRODUCTS

2.1 CAST ALUMINUM SERVICE PIT COVER

A. The pit cover shall consist of a round cover that fits into a lip formed by the fiberglass shell. The cover shall have a 30” diameter ring with a 23” diameter clear opening. The inner portion of the ring contains a round service cover that shall have an 18” diameter clear opening. The service cover shall be attached to the outer ring by means of a hinge. The entire ring and service cover assembly shall be free to rotate within and be independently removable from fiberglass shell.

B. The complete pit cover shall be certified to withstand an aircraft wheel load of 50,000 pounds with a 4:1 safety factor. Complete cover shall have a maximum 0.100” full load deflection at center indicator and deflection “rebound” within 0.010” after load removal. A test report shall be submitted for a prototype cover of the same style as to be provided. The test shall have been conducted or witnessed by an independent testing company and the results confirmed and stamped by a licensed engineer.

C. Material shall be cast aluminum, ASTM B26, alloy A356.0, temper T6. Cover components shall be free of: casting defects that affect structural performance; visible shrink porosity cavities; fillers, paints or weldments meant to hide defects. Weight bearing mating flange surfaces of the pit and cover shall
be flat to within 0.050” total indicator reading. Service lettering shall be abrasion, corrosion and chemical resistant. Covering of portions of the pit cover with paint or placards for information or safety is allowed.

D. The 18” service cover hinge shall open to 180 degrees with a maximum lift force of 25 pounds. The service cover and ring shall both have an “O” ring type gasket to limit the ability of water to enter the pit. The service cover shall include a hand hole on the side opposite the hinge for lifting of the cover. The service cover shall contain a machined notch on the edge of the service cover to allow the cover to be closed when the system is in use.

E. The service cover is to be provided with a hinged stainless steel hanger for storage of the aircraft cable head. Hanger shall be attached to the underside of the service cover and allow for easy access to aircraft cable when cover is opened.

F. The rim shall be provided with threaded holes to accept ½” diameter eye bolts. Eye bolt holes are to be provided with stainless steel bolts, as fillers. When installed, filler bolts shall be flush with the top of the cover. Access to the pit is achieved by inserting eye bolts and lifting the cover.

2.2 SERVICE PIT ASSEMBLY

A. Service pit assembly shall be sized and fabricated to house a minimum of 60’ of single jacketed, 260A aircraft cable. Minimum pit size shall be 36” x 42” x 60” high.

B. Service Pit shell shall be constructed of RTRP (Reinforced Thermosetting Resin Plastic) a minimum of 3/8” thickness. Provide a 4” threaded PVC drain coupling with cap on the bottom of one pit wall. Drain coupling orientation shall be coordinated with storm drainage system. The integral top flange shall require no extraneous material, weldments or strong backs to support the cover.

C. The pit bottom shall slope to channel water to the drain connection.

2.3 SERVICE PIT INTERNAL COMPONENTS

A. All the pit internal components shown or described in the plans and specifications shall be provided by the pit manufacturer as a complete factory assembled package.

B. A cable guide shall be provided to allow unrestricted extraction of the cable from the pit and to guide the cable into the storage portion of the pit. The cable guide frame shall be stainless steel and easily removable to allow personnel entry into the pit for maintenance. The guide itself shall have a minimum of four rollers, one on each of four sides and be securely mounted to the stainless steel guide frame.

C. Conduit penetrations shall be factory installed. Conduit penetrations shall be made through a stainless steel flange with welded male nipples mounted to the pit wall. Stainless steel flange shall be sealed to the pit wall to prevent water penetration. Conduit penetrations shall be furnished with sealing fittings on the inside of the pit. Conduit seals shall be Class1, Division 1, Group D, UL886 labeled. Service pit shall include the following conduit penetrations: One 3” conduit for the 400 Hz transmission cable. One 1” conduit for the control cable.

1. Anti-oxidant lubricant shall be applied to all conduit threads.

D. Provide a static grounding stud on the interior wall of the pit with external point of connection to the grounding grid.
E. Junction Box

1. Junction box shall be 16” x 16” x 8” cast aluminum, NEMA 7 for use in locations classified as Class 1, Division 1, group D. The junction box shall be UL 886 labeled. The aluminum junction box cover shall be constructed with an external flange with “O” ring gasket seal. The cover bolts shall be stainless steel.

2. The junction box shall have external mounting feet and mount vertically to the pit wall with the hinge on either the left or right side to provide ease of cable replacement. Junction box support and attaching hardware shall be stainless steel.

3. The junction box will be utilized for the termination of the aircraft cable power and control wires. Sufficient space shall be provided to meet UL and NEC cable bending radius codes. The junction box input power block shall be capable of landing #4/0, 7C cable. Output lugs for the 400 Hz aircraft cable shall have 3/8” studs. Terminal blocks for the E/F circuit, aircraft cable ON/OFF pushbuttons, equipment ground and control wires shall have #10 lugs or terminal strips. All terminal blocks and strips shall be securely mounted to the junction box.

4. The junction box penetration for the aircraft cable shall be provided with a 2” sealing fitting and a stainless steel strain-relief device.

END OF SECTION 26 99 03
SECTION 26 99 04 – 400 Hz TESTING, ADJUSTING AND BALANCING

PART 1 – GENERAL

1.1 SUMMARY
A. The Drawings and general provisions of the Contract, including General and Supplementary Conditions, apply to Work of this section.

1.2 SCOPE
A. Resistive and reactive test, adjust, and balance the following components of the 400 Hz system
   1. Motor-Generator
   2. Gate box

1.3 References
A. The publications listed below form a part of this specification to the extent referenced and applicable. The publications are referred to in the text by the basic designation only.
   2. National Fire Protection Association (NFPA) 70
   3. National Electrical Code (NEC)

1.4 SUBMITTALS
A. Procedures and Agenda: Submit a synopsis of the testing, adjusting, and balancing procedures and agenda proposed to be used for this Project.
B. Maintenance Data: Submit maintenance and operating data that includes how to test, adjust and balance the 400 Hz system.
C. Sample Forms: Submit sample forms to be used to record test data.
D. Draft Reports: Upon completion of testing, adjusting and balancing procedures, prepare draft reports. Draft reports may be hand written, but must be complete, factual, accurate, and legible. Organize and format draft reports in the same manner specified for the final reports. Submit one (1) hard copy and one (1) electronic copy of the draft reports.
E. Final Report: Upon verification and approval of draft reports, prepare final reports, type written, and organized and formatted as specified below. Submit one (1) hard copy and one (1) electronic copy of the final reports to be added to system Operation and Maintenance Manuals.
F. Report Format: Bind copies of report forms complete with schematic systems diagrams and other data in 1 reinforced, vinyl, three-ring binder. Provide binding edge labels with the Project identification and a title description of the contents. Separate copies by divider tabs that indicate copy number. Divide the contents of each report into the below listed divisions, separated by divider tabs:
   1. General Information and Summary
   2. Motor-Generator
   3. Gate box
4. Testing Instrumentation

G. Report Contents: Provide the following minimum information, forms, and data:

1. General Information and Summary: Inside cover sheet to identify Owner, Architect, Contractor, and Project. Include addresses and contact names. Include in this division a short summary describing the 400 Hz system and the objective of the testing, adjusting, and balancing of the system.

2. The remainder of the report shall contain the appropriate hours submitted earlier for review. Prepare a schematic diagram for each item of equipment and system to accompany each respective test form.

3. Testing Instrumentation: Include load bank information and list of equipment to be used for the procedures along with catalog cut-sheets and operating manual of testing instruments.

1.5 EXPERIENCE

A. Personnel performing test, adjusting, and balancing of the 400 Hz system shall have 5 years’ minimum actual experience in the installation and testing of 400 Hz system.

1.6 PROJECT CONDITIONS

A. Systems Operation: System shall be fully operational prior to beginning procedures.

1.7 SEQUENCING AND SCHEDULING

A. Notify the Architect/Engineer 14 days prior to beginning the procedures. The Architect/Engineer reserves the right to witness the procedures and request adjustments or additional measurements in the field as conditions warrant.

PART 2 – PRODUCTS

A. Not Applicable

PART 3 – EXECUTION

3.1 MISCELLANEOUS

A. Obtain necessary approvals, acceptances and permits before commencing with testing, adjusting, and balancing.

B. Perform test as specified, recommended by the manufacturer, required by the codes and additional tests deemed necessary by the Architect to ensure proper operation and function of the equipment meets the performance specified.

C. Perform operational tests before Work is concealed and only after notifying the Architect/Engineer that items are ready.

D. Conduct tests in a safe and orderly manner with qualified trained personnel in accordance with safety codes and local ordinances.
Section 26 99 04 | Testing, Adjusting and Balancing

E. Correct deficiencies resulting from tests.

3.2 MOTOR-GENERATOR

A. Test Instruments: The test plan shall list make and model number and provide a functional description of the test instruments and accessories and shall describe the setup of the tests to be conducted.

B. Verify and record correct termination of input, output and ground conductors. Verify and record correct termination of paralleling conductor. Inspect terminations inside each motor-generator for looseness as a result of shipping. Tighten and/or repair terminations as required.

C. Apply 60 Hz power to each motor-generator. Measure and record input voltage to motor-generator at no load. Compare to meter display on motor-generator. Adjust meter reading as necessary.

D. Press start button of each motor-generator. Measure and record output voltage and frequency at no load. Compare to meter display in motor-generator. Adjust meter reading as necessary. Verify and record correct operation of paralleling circuit. Reverse master and slave designations and repeat measurements.

E. Operate each control, switch, input/output device that is capable of being operated manually a minimum of 3 times, demonstrating satisfactory operation each time.

F. Run each unit continuously a minimum of 2 hours at no load. After each hour measure and record output voltage and frequency. Verify operation of converter is within specified limits.

3.3 SERVICE TRANSPORT UNIT

A. Extend and retract the Passenger Boarding Bridge (PBB) to verify non-binding operation of the PBB mounted Service Transport Unit, as applicable.

3.4 GATEBOX, PUSHBUTTON ASSEMBLY, AIRCRAFT CABLE ASSEMBLY

A. Test Instruments: The test plan shall list make and model number and provide a functional description of the test instruments, load banks and accessories and shall describe the setup of the tests to be conducted.

B. Inspect the installation of each gate box by the Contractor. Verify and record correct termination of input, output, and ground conductors. Inspect terminations inside each gate box for looseness as a result of shipping. Tighten and/or repair terminations as required.

C. Verify and record proper operation of cable hoist(s) as controlled from the pushbutton indicated on the aircraft ground power cable head and from the remote pushbutton assembly mounted on the PLB lift column or where otherwise indicated.

D. Verify and record the operation of the gate box output contactor(s) via the pushbutton located in the aircraft ground power cable head and via the remote pushbutton assembly with indicator lamps mounted in the PLB lift column or where otherwise indicated.

E. Verify and record the aircraft “E&F” interlock operation of each gate box output contactor.

F. Measure and record the 400 Hertz no load voltage at the plug end of each aircraft ground power cable associated with each gate. The average line to neutral voltage shall be 118V± 0.5 at no load and 115V± 0.5 for the additional tap.
G. Measure and record the full load voltage at the plug end of each aircraft ground power cable associated with each gate. Full load shall be 90 KVA with a 0.8 lagging power factor for single output gate boxes and 140 KVA or 180 KVA with a 0.8 lagging power factor for dual output gate boxes. The line drop compensators shall be set to prevent average line to neutral voltage from dropping below 110V at full load. If a conflict exists between this specification and referenced Standards, the most stringent or current Airport requirements shall be utilized as acceptable settings. Additional load test shall be performed independently for purely reactive load of 54 KVAR and purely resistive load of 72 KW. Test results shall satisfactorily meet Airport’s current requirements for the 400 hertz gate box as specified under Section Division 26, to be acceptable.

H. Operate each control, switch, input/output device that is capable of being operated manually a minimum of 3 times, demonstrating satisfactory operation each time.

3.5 FIELD TEST

A. Resistive and reactive test, adjust, and balance the following components of the 400 Hz system.
   1. Motor-Generator
   2. Gate box

3.6 FIELD QUALITY CONTROL

A. As per Contract Closeout requirements.

END OF SECTION 26 99 04
SECTION 26 99 05 – 60/400 Hertz MOTOR-GENERATOR SET 400 KVA/400 KW

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. This specification describes and defines the construction and performance requirements for a 400 kilovolt-amps (kVA)/400 kilowatt (KW) motor-generator (MG) used to convert 60 Hertz (Hz), 480 Volts (VAC) to 400 Hertz (Hz), 575 volts (VAC) power. Motor-generator shall be a complete package including controls and safeties as specified herein.

1.2 REFERENCES

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

1. Institute of Electrical and Electronic Engineers (IEEE). 115 Test Procedures for Synchronous Machines.
   b. MIL-STD-705 (Rev. C) Generator Sets, Engine Driven, Methods of Tests and Instructions.
4. National Electrical Manufacturers Association (NEMA)
   a. NEMA 250, Type 1 Enclosures for Electrical Equipment
   b. NEMA MG 1 1998 (Rev. 1) Motors and Generators.
5. International Organization for Standardization (ISO)
   a. ISO 9001 Quality Management Systems
   b. ISO 281-1990: Bearing dynamic load ratings and rating life

1.3 QUALITY ASSURANCE

A. Manufacturer Qualifications

1. The Airport has approved Kato Engineering’s 400 Hz 400KVA/400KW Motor-Generator Set. Contractor shall furnish and install approved product or an approved equal that meets all the criteria set forth in paragraphs 1.3.A.2 and 1.3.A.3 below.

2. The system manufacturer shall be a company that specializes in 400 Hz system design and that has been in business for a minimum of 15 years and has supplied similar 400 kVA/400KW, 480VAC/60 hertz input, 575VAC/400 hertz output motor-generators as listed by Underwriters’ Laboratories, Inc. (UL), or certified by a Nationally Recognized Testing Laboratory (NRTL) in the United States. The installed 400 kVA/400KW motor-generators must have been in continuous independent and parallel operation for a minimum of 5 years. Contractor shall submit manufacturer’s proof of prior installation and design Specifications on a minimum of 2 projects, from commencement through completion within the last 5 consecutive years.
3. Manufacturer of the motor-generator shall have a quality program certified to ISO 9001. The manufacturer shall provide all services to establish and maintain quality of workmanship on their supplied 400 Hz equipment and to ensure that the mechanical /electrical performance of the components, compliance with drawings, identification and acceptability of all materials, parts and equipment as per latest quality standards of ISO 9001.

B. Existing Equipment Compatibility: The 400 Hz motor-generators shall be compatible with the existing Airport Square D Power Logic monitoring and control system.

C. FACTORY WITNESS TESTING

1. Supplier shall provide a factory test schedule and test procedures not less than 30 calendar days prior to factory testing. This document shall completely define all tests and test procedures. The tests described shall be performed at the manufacturer’s plant and shall be witnessed by Airport representatives if desired. Otherwise a full report shall be provided to the Owner for review and approval.

2. Components shall be tested by operating at full 400 Hz, 400 kVA/400 kW name plate rating to determine the suitability for independent and parallel operation per Part 1.3 line C.2 of this section.

3. The motor generators shall be tested in accordance with applicable sections of MIL-STD- 705C and IEEE Standard 115 to verify the parameters listed below and test results shall be submitted to the Airport Project Manager for review and approval:
   a. Insulation Resistance and Dielectric Strength
   b. Winding Resistance
   c. Voltage Transients and Recovery Time
   d. Voltage Regulation
   e. Short Circuit Current (Steady State)
   f. Efficiency
   g. Voltage Adjustment Range
   h. Vibration Measurement

4. The acceptance criteria for the motor-generators shall be the performance specifications herein stated. The motor-generators shall be operated under full load at the factory with no failures. The proper operation of all motor-generator controls, alarms and metering devices shall be verified at the factory. Proof of verification shall be submitted to Project Manager for review and approval prior to installation.

5. Motor-generator shall conform to NEMA MG-1 except for portions relating to electromagnetic interference and repetition of voltage regulation and required voltage adjustment tests. Each motor-generator shall be tested for compliance with the performance requirements of the equipment. Test results shall be submitted to Project Manager for review and approval.

6. Paralleling tests shall be performed at the factory for all units demonstrating sequential start-up, shut-down and upset conditions under any given load. Factory testing shall document operation of all motor-generators paralleled at full load. Test results shall be submitted to Airport Project Manager for review and approval prior to installation.

1.4 ENVIRONMENTAL CONDITIONS
A. The motor-generator (MG) set shall be capable of withstanding any combination of the following external environmental conditions without mechanical or electrical damage or degrading of operating characteristics:
   1. Operating ambient temperature -10 °C to 40 °C.
   2. Non-operating and storage ambient temperature from -20 °C to 55 °C.
   3. Relative humidity 0-95% for temperatures stated in (a), including condensation from temperature change.
   4. Altitudes ranging from 0-3500’.

B. Motor-generator Room Conditions: All equipment shown for indoor installation shall be suitable for continuous operation in a ventilated room where ambient temperature is between +50 °F to +90 °F with excursions to +105 °F.

1.5 WARRANTY

A. The 400 Hz system shall have a warranty as specified in Contract Documents.

B. The manufacturer's warranty shall include a guarantee of performance, the requirements of which are defined herein. The manufacturer shall guarantee a continuous high operational availability for all their supplied motor-generators which are expected to achieve 99% uptime on 24 hour-7-day basis as measured in 30-day periods.

C. The manufacturer shall warrant that all materials and equipment furnished under this contract will be new and of good merchantable quality, free from defects in design, workmanship, and materials.

D. All materials and equipment that are furnished under the terms of this contract shall be warranted against defective workmanship, faulty material, defective design, and other damage or failure under normal operation of the equipment for the warranty period. Each item of equipment, or part thereof, proving to be defective within the specified period of the warranty shall be replaced, free of defect, without cost to the Airport.

E. The warranty period shall be the manufacturer's standard warranty period, but not less than a minimum of 2 years. The warranty period shall begin from the date of written project final acceptance by the Airport or designated representative.

F. The warranty shall include all required preventive maintenance and parts at no additional cost to the Airport.

G. The manufacturer, or their authorized representative, shall make a final inspection of the installation during final completion. The inspection shall verify that the installation and interconnection of the 400 Hz system are adequate to ensure the warrantee for the motor-generators and that all of their components are in force and have not been compromised by the contractor's installation methods and procedures.

H. On an on-call basis, the manufacturer shall provide a trained service engineer to the Airport during the period of warranty to handle hardware/software issues that may arise during the usage of system. The engineer shall have sufficient technical qualifications and experience to handle hardware/software issues that may arise during the usage of system. Service personnel shall be on-site within 8 hours of reporting the problem, and the maximum time to repair a reported break down shall be 24 hours after the initial report and the problem shall be fully solved, making the faulty components/system fully operational.
1.6 TRAINING

A. Contractor shall provide a trained manufacturer’s representative to perform on-site maintenance training for up to 15 Airport staff at no additional cost to the Airport. Training shall be performed for a minimum 24 hours, completed as 3, 8-hour days. The Contractor is responsible for scheduling the training and shall do so at a time agreeable with Airport staff. Training agenda and written training manual shall be submitted to the Airport for review and approval, 3 weeks prior to the start of actual training.

PART 2 – PRODUCTS

2.1 MOTOR-GENERATOR

A. General Description: The motor-generator sets shall consist of a single shaft rotor motor-generator assembly for 60 to 400 Hz conversion, with unit-mounted controls on a steel base. Both motor and generator shall have exciters for voltage regulation. Voltage regulator shall have standard controls, protective devices necessary for paralleling and control. The motor-generator shall have open drip-proof construction and the control panel is to be enclosed in accordance with NEMA 250, Type 1. The frame and enclosure must be vermin proof. The motor-generator set and control panel shall be painted ANSI 61 gray.

1. The three-phase, 1200 RPM synchronous motor, with a 480 volt, 60 Hz rated input shall be adjustable to maintain a unity power factor at full load and operate on a constant excitation regardless of load and with adequate horsepower to drive the generator at 120% of rated load.

2. The three phase, 1200 RPM synchronous generator with 575 VAC, 400 Hz output will have a minimum full load capacity of 400 kVA, 400kW at unity power factor.

3. The generator shall be rated 400 kVA, 400 kW at unity power factor.

4. Motor-generator programmable logic controls (PLC) shall be Allen Bradley SLC series to match software utilized in existing motor-generators. Proprietary or imbedded logic controls shall not be allowed. Software program and control logic shall be turned over to the Airport as part of the O & M manual.

5. Operating and Maintenance (O&M) manual shall be supplied with each unit in 3-ring binders. In addition, a CD shall be provided of the complete O&M manual in .pdf format. The O&M manual shall include the software logic and sequence of operation. Airport shall be given full access to the program in the PLC.

6. The motor-generator shall include a solid state monitor with digital display to display voltage (line-to-line and line-to-neutral for each phase) and current (all three phases). The monitor shall be Square D Power Logic model PM850 and shall be visible on the front of the control enclosure. The power monitor shall be factory wired to current transformers (CT’s) and potential transformers (PT’s) in the control cabinet and communications wires routed to a customer interface terminal strip.

2.2 MANUFACTURER

A. Motor-generators shall be manufactured by Kato Engineering Inc. or approved equal.

2.3 CAPABILITY AND PERFORMANCE REQUIREMENTS
A. Overload Capability: Satisfactory operating time is based on not more than 1 overload in 24 consecutive hours of operation.
<table>
<thead>
<tr>
<th>Percent of Full Load</th>
<th>Satisfactory Operating Time</th>
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<tbody>
<tr>
<td>125%</td>
<td>5 minutes</td>
</tr>
<tr>
<td>110%</td>
<td>120 minutes</td>
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B. Efficiency: The efficiency of the motor-generator including the control panel shall be not less than 88% at 100% rated load and rated power factor, measured as a ratio of the input power to output power.

C. Short Circuit: When a 3-phase symmetrical short circuit is applied to the generator, the generator shall be capable of sustaining at least 300% of rated current for not less than 10 seconds duration or not less than the time required for the integral system protective devices to interrupt the fault.


E. Frequency Characteristics Input/Output: The motor-generator shall provide 400 Hz output at 60 Hz input. The steady-state limits shall be:
   1. Regulation shall not exceed plus or minus 0.5%.
   2. Deviation change rate shall not exceed values shown in Figure “7” of MIL-STD-704F.
   3. Transient limits shall not exceed values shown in Figure “5” of MIL-STD-704F upon sudden application or removal of half load at rated power factor.
   4. Modulation shall not exceed 0.5%.

F. Voltage Characteristics: Initial voltage buildup shall be completely automatic. The output voltage shall be capable of being adjusted over a minimum range of plus or minus 10% from the rated voltage.
   1. The steady-state limits shall be:
      a. Regulation shall not exceed plus or minus 0.5% from no load to full load.
      b. Drift shall not exceed plus or minus 0.5% over a 24-hour interval for an ambient temperature range of 10 ºC to 50 ºC.
   2. Modulation shall not exceed 0.5%.

G. Transient Limits:
   1. The step-load change shall not exceed plus or minus 5% for step-load changes equal to 20% of full load.
   2. The full load change shall not exceed plus or minus 25% at rated power factor in compliance with MIL-STD-704E.
   3. The recovery time shall not exceed 95% voltage for more than 150 milliseconds and within regulation band in 250 milliseconds.
   4. The parallel load change shall not exceed the value of the unit load change transient divided by the number of units paralleled or a no load change transient of 3%.

H. Modulation shall not exceed 0.5%.
I. The Line-to-Neutral Phase-Voltage Unbalance:

1. A balanced load shall not exceed 1% between individual line voltages.

2. With an unbalanced load, it shall not exceed 4% for one (1) line voltage from the average of the 3-line voltages, with 1/3 rated current on 1-phase and no load on the other 2 phases.

J. Waveform Characteristics:

1. With a balanced linear load:
   a. The total RMS harmonics shall not exceed 3% line-to-line and line-to-neutral.
   b. The maximum single RMS harmonic shall not exceed 2% of the fundamental at the steady-state voltage.

2. The unbalanced load of one third rated current on one phase and no load on the other two phases, total RMS harmonic shall not exceed 4% line-to-neutral. The deviation factor shall not exceed 0.1 per NEMA MG1.

2.4 MOTOR-GENERATOR SET FABRICATION

A. General Configuration: The motor-generator shall be a single shaft unit with individual exciters for the motor and the generator, an automatic voltage regulator system, necessary devices for automatic unmanned paralleling and control. All components shall be mounted on a common rigid steel base with the rotor assembly statically and dynamically balanced so as not to exceed a 0.001” double amplitude indicator reading. The noise level shall not exceed 95 decibels at a distance of 3’ from the front of the set and at approximately one-half the set height.

B. Bearing Requirements: The bearings shall have a minimum calculated 100,000 hours of L-10 life as defined by ISO 281, when properly lubricated. The bearings shall be equipped with grease fittings extended to the outer surface of the MG Set. Greasing of the bearings shall not require a shutdown of the motor-generator set. It shall be possible to replace either bearing without removing the rotor from the stator.

C. Synchronous Machine: The motor-generator shall be a brushless type, self-ventilated, of drip-proof construction with windings which are impervious to oil, solvents, moisture, mild acids and alkali. All terminals are to be identified on the wiring diagrams. The motor pole alignment detector shall automatically align the two motors for parallel operation without mechanically moving the generator stator.

D. Insulation: The insulation shall meet the requirements of MIL-E-917, Class F, 100% vacuum pressure impregnated epoxy for synchronous machines. Asbestos insulation is prohibited. All epoxies are to be non-organic to prevent the support of fungus growth. The temperature rise will not be greater than 95 °C above a 40 °C ambient temperature.

E. Voltage Regulation System: The voltage regulator shall stabilize the output voltage within one minute after start-up and shall remain within a total regulation band of 0.5% within the units rating. The voltage regulator will sense each of the three phases for regulation of cyclic loads.

F. Stator Coils: Stator coils shall be machine wound, wrapped and pre-formed prior to hand placement in the stator slots.

G. Exciter System: The exciter system shall be a brushless synchronous system utilizing two separate, shaft-mounted, three-phase, silicon-diode bridge assemblies to supply the motor and generator...
fields. The exciter shall use three-phase high-frequency revolving armature excitation current, full-wave rectified through six silicon rectifiers mounted in heat sinks. The excitors are shaft mounted and positioned in the air stream for maximum heat dissipation. Diode PIV rating shall be at least twice the peak operating voltage.

H. Dimensions: The size of the motor-generator complete with unit mounted controls shall not exceed 106” L x 52” W x 96” H and net weight shall not exceed 15,000 lbs. for installation to an existing equipment room and foundation.

2.5 CONTROL CABINET

A. Control Cabinet: All controls, indicating lights, protective devices, paralleling system and instruments shall be in the unit-mounted control cabinet. All wiring must have ample service loops and be protected from abrasion. Wiring and wiring harnesses are to be secured at least each 6”. All terminals are to be identified and shown on the wiring diagrams. All components must meet the requirements of UL 508 Industrial Control Equipment and be so labeled.

B. Input Motor Controller: The synchronous motor shall be started and stopped with a reduced current synchronous motor controller equipped with overload protection. The motor starting current shall be limited to 200% of running current. The field windings and rectifier assembly shall be protected against damage due to surges during starting or pulling out-of-step. Provision shall be made to permit remote operation.

C. Output Disconnect: The 400 Hz output shall be controlled by an electro-mechanical contactor. Provide circuit breaker disconnect of the 400 Hz power. The control circuit shall be protected by fuses. Output breaker shall have an externally mounted operating handle using a cable or hardware mechanism to remotely operate the breaker.

D. Auto-Start Feature: Motor-generator shall have the ability to restart autonomously when the controls are set in the automatic mode. Master unit shall start if all protective devices are satisfied and 480V, 60 Hz power is supplied to the unit or after a 60 Hz power interruption.

2.6 PROTECTIVE CONTROLS

A. Protective Controls: Relays, instrument transformers and circuitry on the generator's 400 Hz output necessary to provide protective control shall be provided. Protection to meet short circuit and overload requirement shall be provided. Protective circuits require operation of a reset button to allow output disconnect closing after a protective device opens the disconnect switch.

B. Overvoltage: Shall protect by tripping the output devices for sustained overvoltage of 15% or more above the normal voltage, using a relay having an inverse time characteristic.

C. Under-voltage: Shall protect by preventing the closing of the output disconnect until the output voltage is at least 95% of the rated output voltage. If, after closing, the voltage decreases to below 90% for longer than 1 second, the relay trips the output devices.

D. Reverse Power: Shall protect by tripping input/output devices for reverse power in excess of 5% of the motor-generator rating.

E. Under-frequency: Shall protect by tripping input/output devices for under-frequency in excess of 5% of the rated output frequency (400 Hz).
F. Over/Under Excitation: Shall protect by tripping input/output devices for excitation above or below the level required to achieve reactive load sharing within the range of 5%.

G. Motor Field Failure: Shall protect by tripping the input contactors for a motor field failure where the line current is in excess of 10% over full load setting.

H. Phase Detection: Shall protect by disabling the start/run controls when a reverse phase rotation of the incoming 60 Hz power is detected and/or if there is a loss of one or more phases of the 480V power.

2.7 CONTROL DEVICES

A. Control Devices: Heavy-duty industrial or switchboard-type devices for manual control, alarm and data indication on the control panel shall be provided.

B. Manual Controls:
   1. Set Control: Provide “Start” and “Stop” pushbuttons to operate the input motor controller.
   2. Provide “Connect” and “Disconnect” pushbuttons to operate the output contactor which connects the generator to the load.
   3. Emergency Stop: Provide an emergency stop/power off pushbutton which is readily accessible and guarded to prevent accidental operation. Operation of this pushbutton shall immediately open the output contactor and disconnect the motor from the 60 Hz power source.
   4. Provide a pushbutton to simultaneously test all indicator LEDs
   5. Provide a “Failure Reset” pushbutton which must be actuated to reset the controls and to allow normal operation after a monitored fault has occurred. Reset circuit will not clear until the fault has been cleared.
   6. Provide an “Alarm Silence” pushbutton to silence audible alarm. Actuating the button shall also illuminate the “Alarm Silenced” indicator.
   7. Circuit Breaker Operation: Provide an operating handle, externally mounted for the output circuit breaker.
   8. Voltage Adjustment: Provide a readily accessible ten-turn potentiometer control that allows for the accurate adjustment (±< 1%) of the generator voltage over a range of ± 10% from the rated voltage.
   9. Mode Selector Switch: Provide a switch that places the motor-generator controls in an automatic, manual or off position.
   10. Master/Slave Switch: Provide a switch that determines the master motor-generator for use in paralleling.

C. Alarm Indication: Nameplates, safety devices, annunciation and summary alarm for the following alarm conditions shall be provided. All indicator lights shall be LED type, having 60,000-hour life.
   1. Motor Field Failure
   2. Motor Overload
   3. Generator Overload
   4. Overvoltage/ Over excitation
   5. Under-voltage/ Under excitation
   6. Under-frequency
   7. Reverse power
8. Failure to parallel

D. Data Indication: Provide the following data indication on the control panel. Meters are to be 3.5 inches square, accurate to within 2% of full scale. Digital meters shall have a minimal overall height of 0.667” and provide a 3-figure readout for values of less than 100.

1. Digital output voltmeter with a transfer switch having three line-to-line positions and one “off” position.
2. Output ammeter reading full-load output in the upper third of the scale with an ammeter transfer switch having three “phase” positions and one “off” position.
3. Digital running-time meter, 99,999 hours full scale.
4. Motor line ammeter to read full motor load current in the upper third scale of the ammeter.

E. Visual Indicators: Provide high-visibility LEDs with an expected lifetime of not less than 60,000 hours for the following:

1. Motor On
2. Generator On
3. Output Breaker Closed
4. Generator On-line
5. Master Unit
6. Slave Unit
7. Automatic Mode
8. Manual Mode
9. Ready to Parallel
10. Paralleling
11. Failure to Parallel
12. Alarm Silenced

2.8 AUTOMATIC PARALLELING

A. Paralleling Control Circuitry: Paralleling is completely automatic for normal operation and manual controls are provided for backup operation. The pole alignment detector automatically adjusts the rotor poles to permit shifting of the unit’s phase angle, as necessary, to parallel and share loads equally with the other motor-generator sets of the installation. The motor-generator sets are equipped with necessary switchgear and switchboards to allow closing of the output contactor only when that motor-generator sets voltage and phase angle matches bus voltage. The paralleling system has the necessary termination for remote operation. Paralleling control and peripheral control shall be an Allen Bradley SLC –controller per Part 2.1 line A.4 of these specifications, integral to the control cabinet.

B. Automatic Paralleling: Provides for unmanned control to start up, load share, load shed and shutdown units as necessary to meet load demand. Manual means for alternating the units to equalize lead machine selection and unit running times between units is provided. The master selector switch selects the unit to be the master unit. The slave units will then be started in sequence after the master unit reaches a predetermined percent of load. The control logic provides a means of bypassing the motor-generator set in which a fault has occurred or to perform the routine maintenance as necessary on any motor-generator set. The automatic paralleling operation functions as follows:

1. When the 400 Hz load reaches a preset level (adjustable from 0 to 100%) of the master’s maximum rating, as measured at the main output bus, the first slave will be “ready” to start, but will be prevented by a time delay relay (adjustable from 1 to 10 minutes). If the load remains over
set point and the time delay period has been reached, the slave will start and be automatically paralleled with the main bus. After phase alignment between the main bus and the unit being paralleled has been achieved, the main output contactor of the slave generator will close and the two motor-generators will share the total load. When these two motor-generators reach the preset rating, the same sequence will bring the next motor-generator on line.

2. Automatic cross-current compensation sensing and control circuitry are provided to insure that load sharing within 5% will be maintained from no-load to full load output rating of the combined motor-generators.

3. To prevent “Short Cycling”, once a machine is started, it is controlled to run at least one hour (time is adjustable from 5 to 60 minutes) regardless of load.

4. When the 400 Hz load shared by the motor-generators decreases to 30% (adjustable from 5 to 50%) of the combined output of the connected motor-generators as sensed at the main output bus, the slaves are turned off in sequence.

5. In event of a failure of a motor-generator, the problem generator will be shut down and the next available motor-generator set started and brought “on-line.”


D. Paralleling Circuitry Malfunction: The output disconnect shall automatically open upon failure of that set to properly parallel or share load with any other set in a parallel group.

1. Reverse Power: Shall protect by tripping/opening the output device when reverse power exceeds 10% of the motor-generator rating.

2. Over/Under Excitation: Shall protect by tripping/opening the output device when excitation above or below the level required to achieve reactive load sharing within the range of 25% of the unit rating.

2.9 OTHER CONDITIONS

A. Control Circuit Transformer: Provide a transformer with a fused 120 volt, 60 Hz secondary for operation of control and indicating devices. The transformer shall conform to UL 504.

B. Terminal Blocks: Suitable clearly and permanently labeled terminal blocks which are readily accessible shall be provided in each separately mounted unit for the interconnecting wiring and for the power supply and load connections. Provisions shall be made to land two conductors per phase on both the incoming and outgoing connections for wire up to 500 MCM or as shown on the plans whichever is greater.

C. Lifting Provisions: Two forklift openings on each side of the base meeting NEMA MG-1 requirements shall be provided.

D. Terminals shall be provided for connection to a voltage-free normally open contact rated 120V, 1A, for remote summary fault indication.

E. Seismic Vibration Isolators: Vibration isolators designed, specified and sized by the motor-generator manufacturer shall be provided, for installation by the contractor.

END OF SECTION 29 99 05
APPENDIX A – MASTER LIST OF MANUFACTURERS

This section provides the Master List of Manufacturers approved for the Electrical 400 Hz to be used in SFO organized by section and subsection. Contractors are responsible for any extra cost incurred when evaluating products by manufacturers that are not listed are approved equals.

26 99 00 – 400 Hz Gatebox with LDC

1. 90 KVA OR 180 KVA GATEBOX WITH LDC
2. MCM Engineering
3. Or approved equal

26 99 01 – 400 Hz Aircraft Ground Power Cable

1. J&B Aviation
2. Or approved equal

26 99 02 – 400 Hz Twisted Cable

1. Service Wire Co.
2. Or approved equal

26 99 05 – 60/400 Hz Motor-Generator Set 400 KVA/400KW

1. Kato Engineering
2. Or approved equal
Standards Adoption

The “Electrical – 400 Hz” Version 3.1, March 2018 standards were adopted by the Standards Committee on April 5th, 2018, and are effective immediately.

Confirmed:

[Signature]

Geoffrey W. Neumayr, Standards Committee Chair