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Marine Regulatory Agency, Low Voltage Switchboard Components, Rules Comparison

US Department of Homeland Security, US Coast Guard, Title 46 Shipping,
Volume 4, Chapter I, Subchapter J, Part 111

American Bureau Of Shipping (ABS) Publication #2, Rules for Building and
Classing Steel Vessel Rules 2009, Part 4, Chapter 8

American Bureau Of Shipping (ABS) Publication #5, Steel Vessels Under 90 Meters
(295 Feet) in Length, Part 4, Chapter 5

IEEE45-2002 Recommended Practice for Electric Installations on Shipboard

Compiled by John Winbery

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TABLE OF REGULATORY BODY REQUIREMENTS FOR LOW VOLTAGE SWITCHBOARDS
Sheet 1

Component Requirements:	USCG CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Generator Circuit Breaker	<p>111.30-25 (b) (1) “A circuit breaker that meets §111.12–11 and §111.50–5 (2) A disconnect switch or link for each generator conductor, except a switchboard having a draw-out or plug-in type generator circuit breaker that disconnects: (i) Each generator conductor; or (ii) If there is a switch in the generator neutral, each ungrounded conductor.</p> <p>111.12-11(d) The pickup setting of the longtime overcurrent trip of a generator circuit breaker must not be larger than: (1) 115 percent of the generator rating for a continuous rated machine; or (2) 115 percent of the overload rating for a machine with a 2-hour or greater overload rating.</p> <p>111.12-11(c) (1) Open upon the shutting down of the prime mover;</p> <p>111.12-11(c)(3) Not have an instantaneous trip with the exception that an instantaneous trip is required if: (i) Three or more alternating-current generators can be paralleled”</p>	<p>4-6-2 / 9.3.1 A circuit breaker must be provided for all generators over 25 kW or that are operated in parallel. Generators below 25 kW and not operated in parallel may be protected by fuses. The breaker must open on shutdown of the generator engine.</p> <p>9.5.2(c)Undervoltage Means are to be provided to prevent the generator circuit breaker from closing if the generator is not generating and to open the same when the generator voltage collapses. 4-6-2/9.5.1 Short-time delay trips are to be provided with circuit breakers for AC generators. and 9.5.2(a) for instantaneous trips where three or more generators are arranged tor parallel and set in excess of the max. short circuit contribution of the largest generator.</p>	<p>4-8-2 / 9.11.1 Generators are to be protected by circuit breakers providing long-time delay overcurrent protection not exceeding 15% above either the full-load rating of continuous-rated machines or the overload rating of special-rated machines. Alternatively, generators of less than 25 kW not arranged for parallel operation may be protected by fuses.</p> <p>9.11.2 Requires short time trips set at less than short circuit current of the generator and require instantaneous trip for two or more generators that are arranged for parallel operation that are to be set in excess of the maximum short-circuit contribution of the individual generator..</p>	<p>7.5.1 “It is recommended that generators be protected with molded case or power circuit breakers. The overcurrent trip setting should not exceed 115% of the generator full load current. If a molded case circuit breaker is used, a circuit breaker rated for continuous operation at 100% of its trip rating should be used. If a power circuit breaker is used, the use of short-time and long-time breaker trips is recommended to permit better coordination with other breakers or fuses in the distribution system. Where three or more generators are operated in parallel, breakers should have instantaneous trips</p> <p>7.5.9 When a shutdown is initiated, it is recommended that in multiple generator applications, the generator main circuit breaker or contactor be opened by either the prime mover shut-down system or the generator control panel.”</p>
Draw-out or Plug-in Circuit Breakers.	<p>111.30-4 “Circuit breakers, when installed on generator or distribution switchboards, must be mounted or arranged in such a manner that the circuit breaker may be removed from the front without unbolting bus or cable connections or deenergizing the supply, unless the switchboard is divided into sections, such that each section is capable of providing power to maintain the vessel in a navigable condition, and meets §111.30–24 (a) and (b).”</p>	<p>4-6-4 / 11.1.3 Isolation. Electrical System to be able to isolate breakers for removal while maintaining essential services or breakers are to be removable without disconnecting connections or deenergizing supply.</p>	<p>4-8-3 / 5.3.3(c) <i>Removable mounting.</i> “Circuit breakers are to be mounted or arranged in such a manner that the breakers may be removed from the front of the switchboard without first deenergizing the bus bars to which the breakers connect.”</p>	<p>Clause 8.3: “Power circuit breakers shall be drawout type. The insulated case circuit breakers shall be drawout type, and the molded case breakers shall be mounted on marine dead-front removable (plug-in) connectors (both line and load) to facilitate maintenance and replacement without a complete switchboard outage.”</p>



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Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Generator Pilot Light	111.30-25(b)(3) requires: "A pilot lamp connected between the generator and the circuit breaker."	4-6-4 Table 7, Item 1 requires: "A pilot lamp for each generator connected between generator and circuit breaker."	4-8-3 Table 5, Item 1 requires: "An indicator light for each generator connected between generator and circuit breaker."	Clause 7.6 requires: "An indicator light permanently connected to the generator side of each generator circuit breaker."
Ammeter and Selector Switch	111.30-25(b)(4) requires: "An ammeter with a selector switch that connects the ammeter to show the current in each phase."	4-6-4 Table 7, Item 5 requires: "An ammeter for each generator with a selector switch to read the current of each phase."	4-8-3 Table 5, Item 4 requires: Same as under 90 meter rules.	Clause 7.5.10 requires "an ammeter (with a selector switch to meter all phases)" Clause 8.5 requires 1% accuracy, 250 deg. scale analog switchboard type or equal electronic instruments.
Voltmeter and Selector Switch	111.30-25(b)(5) "A voltmeter with a selector switch that connects the voltmeter to show the: (i) Generator voltage of each phase; and (ii) Bus voltage of one phase." 111.30-25(f)(3): "(f) For each shore power connection each switchboard must have: (3) One of the voltmeters under paragraph (b)(5) of this section connected to show the voltage of each phase of the shore power connection"	4-6-4 Table 7, Item 6 requires: "A voltmeter for each generator, with a selector switch to each phase of the generator and to one phase of the bus."	4-8-3 Table 5, Item 5 requires: Same as under 90 meter rules.	Clause 7.5.10 requires: "a voltmeter, and a voltmeter selector switch (to provide metering of all phases and one phase of bus voltage, if applicable)." Clause 8.5 requires: " All electrical indicating instruments should be switchboard-type or equivalent electronic-type" The switchboard-type or electronic-type instruments should have 1% accuracy and, in the case of switchboard type analog instruments, preferably have a 250° circular scale."
Wattmeter	111.30-25 d) "If generators are arranged for parallel operation, each switchboard must have: (2) An indicating wattmeter for each generator."	4-6-4 Table 7, "Where generators are arranged for parallel operation, an indicating wattmeter is to be fitted for each generator."	4-8-3 Table 5, same as under 90 meter rules.	Clause 7.5.10 requires: "For generators intended for parallel operation, the metering should be as described in this subclause, and in addition a wattmeter should be installed." Clause 8.5 also requires 1% accuracy, 250 deg. scale analog switchboard type or equal electronic instruments. See quoted clause for voltmeter.



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Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Synchroscope and Synchronizing Lights	111.30-25(d) "If generators are arranged for parallel operation, each switchboard must have: (3) A synchroscope and synchronizing lamp that have a selector switch to show synchronization for paralleling generators."	4-6-4 Table 7, Item 8: "A synchroscope or synchronizing lamps with selector switch for paralleling in any combination"	4-8-3 Table 5, Item 7: Same as for Under 90 Meter Rules.	Clause 7.6 " Where two or more generators are to operate in parallel, a synchroscope and synchronizing lamps with selector switch to permit manual paralleling in any combination should be used." Clause 8.5 requires 1% accuracy, 250 deg. scale analog switchboard type or equal electronic instruments.
Frequency Meter	111.30-25(e) "Each switchboard must have the following: (2) A frequency meter with a selector switch to connect the meter to each generator."	4-6-4 Table 7 Item 11: "A frequency meter with selector switch to connect to any generator."	4-8-3 Table 5, Item 10: Same as for Under 90 Meter Rules.	Clause 7.5.10 "a frequency meter" (Addition of a selector switch to connect to each generator is acceptable to both USCG and ABS. A reasonable owner's rep. would not insist on a meter for each generator.) Clause 8.5 requires 1% accuracy, 250 deg. scale analog switchboard type or equal electronic instruments.
Automatic Voltage Regulator	111.30-25 (b)(6) "A voltage regulator and voltage regulator functional cut-out switch." (However, a letter ruling allows the voltage regulator to be mounted on the generator if the voltage adjusting rheostat is mounted in the switchboard. See Note 1)	4-6-4 Table 7 Item 13: "A voltage regulator" <i>3.21.2(a) Voltage Regulators.</i> " A separate regulator is to be supplied for each AC generator. When it is intended that two or more generators will be operated in parallel, reactive-droop compensating means are to be provided"	4-8-3 Table 5, Item 12: "A voltage regulator" <i>3.13.2(a) General.</i> "An automatic voltage regulator is to be fitted for each generator."	Clause 7.4.7 Voltage regulation: "At least one voltage regulator shall be provided for each generator. Clause 7.6: a) An automatic voltage regulator with voltage adjusting device" "As an option, the generator may have dual redundant automatic voltage regulators (a lead and backup unit)."
Manual Voltage Regulator	11.30-25 (c)(1) "A generator field rheostat." (See Note2 for letter ruling that a manual voltage control is required.)	Silent on Subject	Silent on Subject	Clause 7.6 d) "A manual voltage regulator with optional voltage follow feature or a rheostat"



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Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Speed Control for the Prime Mover of Each Generator	111.30-25 (d) (1) "A speed control for the prime mover of each generator;"	4-6-4 Table 7, Item 9: "Control for prime mover speed for paralleling."	4-8-3 Table 5, Item 8: Same as for Under 90 Meter Rules.	. Clause 7.6, "A speed control device for the prime mover of each generator capable of parallel operation should be used."
Insulation Monitoring on Bus.	Silent on subject.	4-6-4, Table 7, Item 4: "A means for continuously monitoring the electrical insulation level to earth, and an audible or visual alarm for abnormally low insulation values."	4-8-3 Table 5, Item 5: Same as for Under 90 Meter Rules.	5.9.7.1 General: "For insulated (ungrounded) distribution systems, a device or devices should be installed that continuously monitor and display the insulation level and give audible and visual alarms in case of abnormal conditions.
Ground Detection.	<p>111.30-25 (e) (1) "Ground detection that meets Subpart 111.05 for the: (i) Ship's service power system; (ii) Normal lighting system; and (iii) Emergency lighting system.</p> <p>111.05-25 Ungrounded systems. Each ungrounded system must be provided with a suitably sensitive ground detection system located at the respective switchboard which provides continuous indication of circuit status to ground with a provision to momentarily remove the indicating device from the reference ground.</p> <p>111.05-27 Grounded neutral alternating current systems. Grounded neutral alternating current system: Grounded neutral and high-impedance grounded neutral alternating current systems must have a suitably sensitive ground detection system which indicates current in the ground connection, is able to withstand the maximum available fault current without damage, and provides continuous indication of circuit status to ground."</p>	Silent on subject	Silent on subject.	<p>5.9.7.2 Ground detection lamps on ungrounded systems: "Ground detection for each ungrounded system should have a monitoring and display system that has a lamp for each phase that is connected between the phase and the ground." 5.9.7.3 Ground detection on grounded neutral ac systems: "Ground detection for each ac system that has a grounded neutral should have an ammeter and ammeter switch that can withstand the maximum available fault current without damage." 7.5.6 Ground-fault detection "When the electrical system is ungrounded, a bus ground-fault indication system is recommended for each bus that has a power source connected and can be isolated by bus disconnect means. See 5.9.7"</p>



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Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Shore Power – Where installed.	111.30-25(f) “For each shore power connection each switchboard must have: (1) A circuit breaker or fused switch; (2) A pilot light connected to the shore side of the circuit breaker or fused switch; and (3) One of the voltmeters under paragraph (b)(5) of this section connected to show the voltage of each phase of the shore power connection.”	4-6-2 9.11.2 Interlocking Arrangement “Where the generator is not arranged for parallel operation with the external or shore power supply, an interlocking arrangement is to be provided for the circuit breakers or disconnecting devices between the generator and the external or shore power supply in order to safeguard from connecting unlike power sources to the same bus.”	4-8-2/11.1.2 Interlock Arrangements “An interlocking arrangement is to be provided between all generators, including the emergency generator, and the shore power supply to prevent the shore power from being inadvertently paralleled with the shipboard power.” 11.1.3 Instrumentation “An indicator light is to be provided at the main or emergency switchboard to which shore power is connected to show energized status of the cable. Means are to be provided for checking the polarity (for DC) or the phase sequence (for three-phase AC) of the incoming supply in relation to the vessel system.”	Clause 8.9.4 Shore power: “The shore power feeder should have a circuit breaker with a pole for each ungrounded conductor installed in the switchboard for connecting power from the shore connection panel to the ship service distribution bus.” “An indicating light should be illuminated when power is available from shore, and one of the switchboard voltmeters should have selector switch capability to read shore power voltage.” “Mechanical or electrical interlocking of the shore power circuit breaker with the generator circuit breakers should be installed unless load transfer paralleling capability is provided.”
Stator Winding Temperature Indicator	Silent on Subject	4-6-4 Table 7, Item 14: “ For alternating current propulsion generator above 500 kW, a stator winding temperature indicator is to be fitted for each generator control panel.”	4-8-3 Table 5, Item 13: Same as Under 90 Meter Rules.	Clause 7.6: “For each generator rated 400 kW and above, a temperature detection instrument with a selector switch (or multifunction device) having positions to read all temperature detectors (RTDs) in each winding should be used. As an alternative, a multifunction device that can display and alarm each of the winding and bearing temperatures may be used.”



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Sheet 6

Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Reverse Power Protection	111.12-11 Generator Protection. (f) <i>Reverse-power and reverse-current trips.</i> Each generator arranged for parallel operation must have reverse-power or reverse-current trips.”	4-6-2 / 9.5.2(b) <i>Reverse Power Protection:</i> “A time-delayed reverse active power protection or other devices which provide adequate protection is to be provided”.	4-8-2 / 9.11.4 Reverse Power Protection: “A reverse power protection device is to be provided for each generator arranged for parallel operation.”	Clause 7.5.2:”When two or more generators are to operate continuously in parallel, each unit should be provided with a reverse power relay to trip the generator breakers in the event of reverse power flow.
Undervoltage and Underfrequency Protection	Silent on subject.	4-6-2 / 9.5.2(c) <i>Undervoltage Protection.</i> ” Means are to be provided to prevent the generator circuit breaker from closing if the generator is not generating and to open the same when the generator voltage collapses. In the case of an undervoltage release provided for this purpose, the operation is to be instantaneous when preventing closure of the breaker, but is to be delayed for discrimination purposes when tripping a breaker.”	4-8-2 / 9.11.6: Same as for Under 90 Meter Rules.	Clause 7.6: “When two or more generators are to operate in an automatic start and parallel mode, a frequency permissive relay and a voltage permissive relay should be provided for each generator. 7.5.3 Undervoltage and overvoltage sensing devices with time delay trips should be considered for protection of the electrical system.
Bus tie or disconnect	111.30-24: “ when the total installed electric power of the ship's service generation system is more than 3000 kW, the switchboard must have the following: (a) At least two sections of the main bus that are connected by: (1) A non-automatic circuit breaker; (2) A disconnect switch; or removable links.”	4-6-4 / 7.15.2 Main Bus Bar Subdivision: “Where the main source of electrical power is necessary for propulsion of the vessel, the main bus bar is to be subdivided into at least two parts which is to be normally connected by circuit breaker or other approved means.”	4-8-2 / 3.13 Main Switchboard: Same as Under 90 Meter Rules.	Clause 8.10 “When the main source of electrical power is necessary for propulsion of the ship, and the aggregate generating capacity connected to a generator switchboard exceeds 3000 kW, the switchboard bus should be divided into at least two sections. The bus sectioning device may be an automatic or nonautomatic circuit breaker, disconnect switch, or other suitable device.”



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Sheet 7

Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Load Shedding	Silent on Subject	<i>4-6-2 / 9.3.3(a) Provision for Load Shedding Arrangements.</i> In order to safeguard continuity of the electrical power supply, automatic load-shedding arrangements or other equivalent arrangements are to be provided.”	4-8-2 / 9.9.1 Provision for Load Shedding Arrangements (2004) “In association with the provision of 4-8-2 / 3.11, and in order to safeguard continuity of the electrical power supply, automatic load-shedding arrangements or other equivalent arrangements are to be provided.”	Silent on Subject
UL 891 Requirements	111.30-5 Construction. (a) “All low voltage and medium voltage switchboards (as low and medium are determined within the standard used) must meet—(1) For low voltages, either section 8.3 of IEEE 45–2002 or IEC 60092–302 (both incorporated by reference; see 46 CFR 110.10–1), as appropriate.”	<i>Silent on Subject</i>	Silent on Subject	Clause 8.3 Low-voltage switchboards: “Switchboards operating at a root-mean-square (RMS) voltage less than 1000 V should meet the requirements of UL 891 or IEC 60947 for dead-front switchboards or IEEE Std C37.20.1-1993, UL 1558-1999, or IEC 60947 for low-voltage, metal-enclosed power circuit breaker switchgear.”
Generator Heaters	Silent on Subject	<i>4-6-4 Table 7 Space Heater Pilot Lamp:</i> Where electric heaters are provided for generators, a heater pilot lamp is to be fitted for each generator.	4-8-3 Table 5, Item 6, Same as Under 90 Meter Rules.	Clause 7.6: “A circuit breaker to feed the heater in each generator via a relay or auxiliary contacts on the generator circuit breaker should be used.” Clause 7.4.5 Means to prevent generator moisture. “These means should be automatically energized when the generator is stopped or at any time that the temperature of the windings or metal parts of the generator are lower than the ambient temperature.”



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Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Nameplates	111.30-15 Nameplates: (a) "Each device must have a nameplate showing the device's function. b) Each nameplate for a circuit breaker must show the electrical load served and the setting of the circuit breaker."	Silent on Subject	Silent on Subject	8.13 Nameplates: "Each switchboard should be fitted with a nameplate stating that it has been constructed for a marine application and should provide the voltage and ampere rating of the main bus, the manufacturer's name, and the date of manufacture. Nameplates for generator, bus-tie, feeder, and branch circuit breakers should include the circuit number and designation, and the rating of the circuit breaker trip elements, or fuse sizes, required for the circuit."
Main-emergency bus-tie.	112.05-3 Main-emergency bus-tie; "Each bus-tie between a main switchboard and an Emergency switchboard must: (a) Disconnect automatically upon loss of potential at the emergency switchboard; (b) Be arranged to prevent parallel operation of an emergency power source with any other source of electric power, except for interlock systems for momentary transfer of loads; and (c) If arranged for feedback operation, open automatically upon overload of the emergency power source before the emergency power source is tripped off the line from the overload." (continued on sheet 9)	4-6-2 / 5.9.4 Interconnector Feeder Between Emergency and Main Switchboards: "The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be protected at the main switchboard against overload and short circuit. The interconnector feeder is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. (continued on sheet 9)	4-8-2 / 5.13.2 Interconnector Feeder between Emergency and Main Switchboards The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. (continued on sheet 9)	Clause 6.4: The emergency switchboard should be supplied during normal operation from the main switchboard by an interconnecting feeder. This interconnecting feeder should be protected against short-circuit and overload at the main switchboard and, where arranged for feedback, protected for short-circuit at the emergency switchboard. The interconnecting feeder should be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. (continued on sheet 9)



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Sheet 9

Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Main-emergency bus-tie (continued)	(c) If arranged for feedback operation, open automatically upon overload of the emergency power source before the emergency power source is tripped off the line from the overload.”	Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard against short circuit. In addition, the circuit protection device at the emergency switchboard on the interconnector feeder is to trip to prevent overloading of the emergency generator.”	5.13.3 Feedback Operation: “Where the emergency switchboard is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit, which is to be coordinated with the emergency generator circuit breaker. In addition, this interconnector feeder protective device is to trip to prevent overloading of the emergency generator which might be caused by the feedback operation.”	“Means shall be provided to prevent auto closing of the emergency generator circuit breaker should a fault occur on the emergency switchboard.”
Emergency generator start and transfer.	112.25-5 Failure of power from the normal source: “If there is a reduction of potential of the normal source by 15 to 40 percent, the diesel engine or gas turbine driving the final emergency power source must start automatically with no load on the emergency power source. 112.25-10 Transfer of emergency loads.(a) When the potential of the final emergency source reaches 85 to 95 percent of normal value, the emergency (Continued)	4-6-2 / 5.5.2(b)i) “ Started automatically upon failure of the main source of electrical power supply and connected automatically to the emergency switchboard – then, those services referred to in 4-6-2 / 5.7 are to be connected automatically to the emergency generator as quickly as is safe and practicable, subject to a maximum of 45 seconds.”	4-8-2 / 5.9.1 Generator “Where the emergency source of electrical power is a generator, it is to be: <i>ii</i>) Started automatically upon failure of the main source of electrical power supply; and <i>iii</i>) Automatically connected to the emergency switchboard supplying those services referred to in 4-8-2/5.5 in not more than 45 seconds.”	Clause 6.4: “Upon interruption of normal power, the prime mover driving the emergency power source should start automatically. When the voltage of the emergency source reaches 85% to 95% of nominal value, the emergency loads should transfer automatically to the emergency power source. The transfer to emergency power should be accomplished within 45 seconds after failure of the normal power source. If the system is arranged for automatic retransfer, the return to normal supply should be accomplished (Continued)



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Component Requirements:	CFR 46, Subchapter J	ABS Under 90 Meter Rules	ABS Steel Vessel Rules	IEEE-45 2002 Revision
Emergency generator start and transfer. (Continued)	loads under §112.15-5 must transfer automatically to the final emergency power source and this transfer must be accomplished in no more than 45 seconds after failure of the normal source of power. (b) When the potential from the normal source has been restored, the emergency loads must be manually or automatically transferred to the normal source, and the final emergency power source must be manually or automatically stopped.”			when the available voltage is 85% to 95% of the nominal value and the expiration of an appropriate time delay. The emergency generator should continue to run without load until shut down either manually or automatically by use of a timing device.”
Bus Bars (all regulatory bodies require that bus bar be copper)	111.30-19 Buses and wiring. “(a) <i>General</i> . Each bus must meet the requirements of either— (1) Section 7.10 of IEEE 45-1998 (incorporated by reference; see 46 CFR 110.10-1); or (2) IEC 60092-302 (clause 7) (incorporated by reference; see 46 CFR 110.10-1).”	4-6-4 / 7.11 “Generator bus bars are to be designed on the basis of maximum generator rating. All other bus bars and bus-bar connections are to be designed for at least 75% of the combined full-load rated currents of all apparatus that they supply, except that when they supply one unit or any group of units in continuous operation, they are to be designed for full load.”	4-8-3 / 5.3.2 Bus bars are to be sized and arranged such that the temperature rise will not affect the normal operation of electrical devices mounted in the switchboard. 4-8-3 / 1.17.1 General “For purposes of rating of equipment other than rotating machinery, a maximum ambient temperature of 45°C (113°F) is to be assumed for boiler and engine rooms, while 40°C (104°F) may be assumed for all other locations.”	8.3 Low-voltage switchboards: Switchboards operating at a root-mean-square (RMS) voltage less than 1000 V should meet the requirements of UL 891 or IEC 60947 for dead-front switchboards or IEEE Std C37.20.1-1993, (UL 891 requires that bus be sized to carry not more than 1000 amps / sq. inch of cross sectional area)

