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NFPA 110 Overview for Generator Set Emergency Power Systems

This material is based on NFPA110-2016

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The views and opinions expressed in this seminar shall not be considered the official position of NFPA and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Participants are encouraged to refer to the entire text of all referenced documents available at NFPA.org. In addition, when it doubt, reach out to the Authority Having Jurisdiction.

Course Objectives

Participants will be able to:

- List NFPA 110 classifications of emergency and standby power systems
- Identify key aspects and intent of NFPA 110 that affect the equipment selection and design of engine-driven generator set emergency power systems;
- Describe various strategies for ensuring generator set starting performance and reliability

NFPA 110 Standard for Emergency and Standby Power Systems - Introduction

- Requirements covering the performance of emergency and standby power systems providing an alternate source of electrical power to loads in buildings and facilities in the event that the primary power source fails.
- Covers installation, maintenance, operation, and testing requirements as they pertain to the performance of the emergency power supply system (EPSS).
- Intent of standard is to achieve maximum system reliability

NFPA 110 - Classification of Emergency Power

- Class - minimum time, in hours, for which the EPSS is designed to operate at its rated load without being refueled or recharged.
- Type - maximum time that the EPSS will permit the load terminals of the transfer switch to be without acceptable electrical power.
- Level - two levels of equipment installation, performance, and maintenance.
  - Level 1 systems shall be installed where failure of the equipment to perform could result in loss of human life or serious injuries
  - Level 2 systems shall be installed where failure of the EPSS to perform is less critical to human life and safety

NFPA 110 - Classification of Emergency Power

- **4.4.4*** Level 1 and Level 2 systems shall ensure that all loads served by the EPSS are supplied with alternate power that meets all the following criteria:
- (1) Of a quality within the operating limits of the load
- (2) For a duration specified for the class as defined in Table 4.1(a)
- (3) Within the time specified for the type as defined in Table 4.1(b)

Table 4.1(a) Classification of EPSSs

Class	Minimum Time
Class 0.083	0.083 hr (5 min)
Class 0.25	0.25 hr (15 min)
Class 2	2 hr
Class 6	6 hr
Class 48	48 hr
Class X	Other time, in hours, as required by the application, code, or user

Table 4.1(b) Types of EPSSs

Designation	Power Restoration
Type U	Basically uninterruptible (UPS systems)
Type 10	10 sec
Type 60	60 sec
Type 120	120 sec
Type M	Manual stationary or nonautomatic — no time limit

Examples of EPSS Classifications

- NFPA 101 Life Safety Code - Means of Egress
- Example of a Level 1 System
  - **Emergency Lighting**
  - **7.9.2.2** New emergency power systems for emergency lighting shall be at least Type 10, Class 1.5, Level 1, in accordance with NFPA110, *Standard for Emergency and Standby Power Systems*.
- Example of a Level 2 System
  - **Means of Egress Components**
  - **7.2.3.12** Smokeproof enclosures - A Type 60, Class 2, Level 2 EPSS for new mechanical ventilation equipment shall be provided in accordance with NFPA 110, *Standard for Emergency and Standby Power Systems*

Strategies for Ensuring a Reliable 10-second Start

- EPSS = Emergency Power Supply System
- EPS = Emergency Power Source (generator set)
- Type and Class requirements apply to the EPSS and not the EPS!
- System level time analysis should be completed
  - Electrical system component selection
  - Evaluate performance of each component

Single Generator Set System

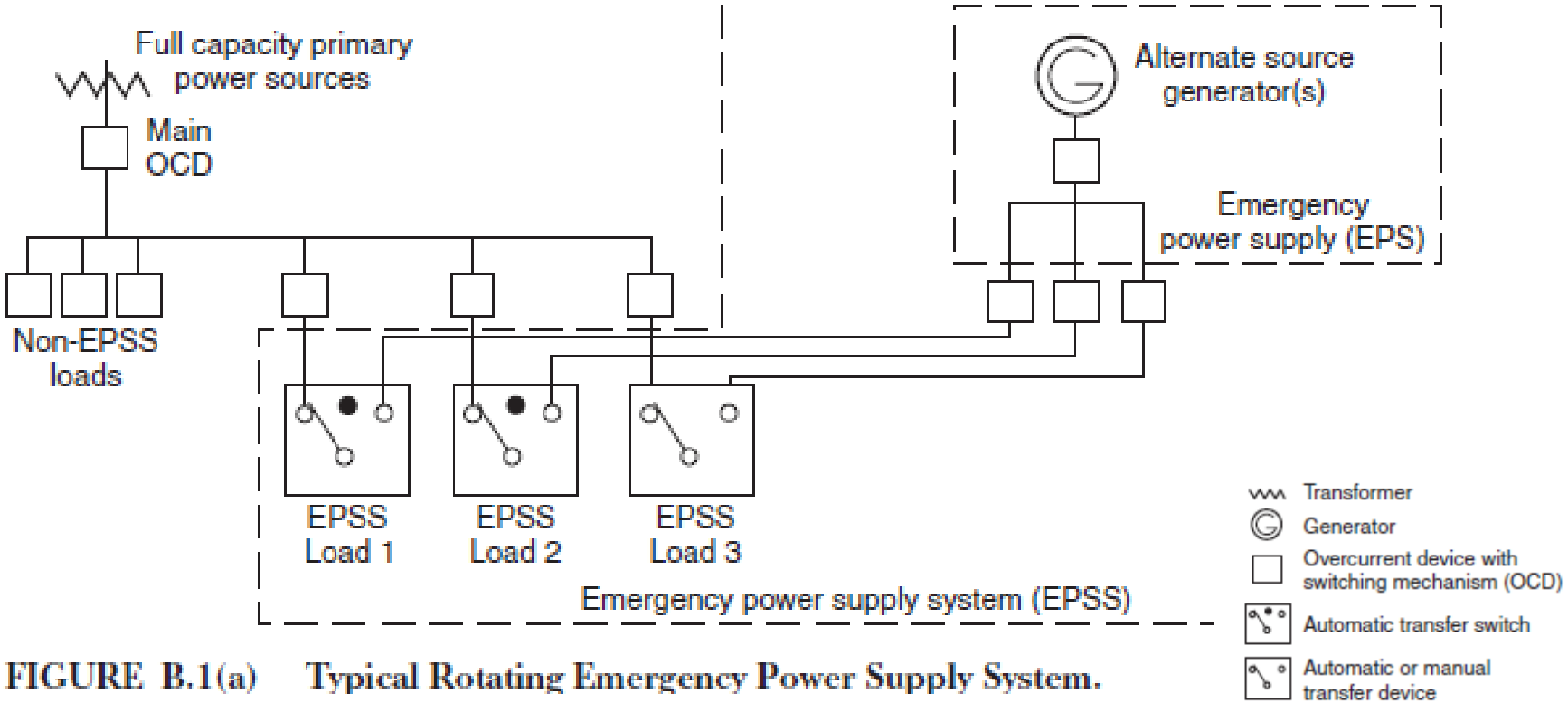


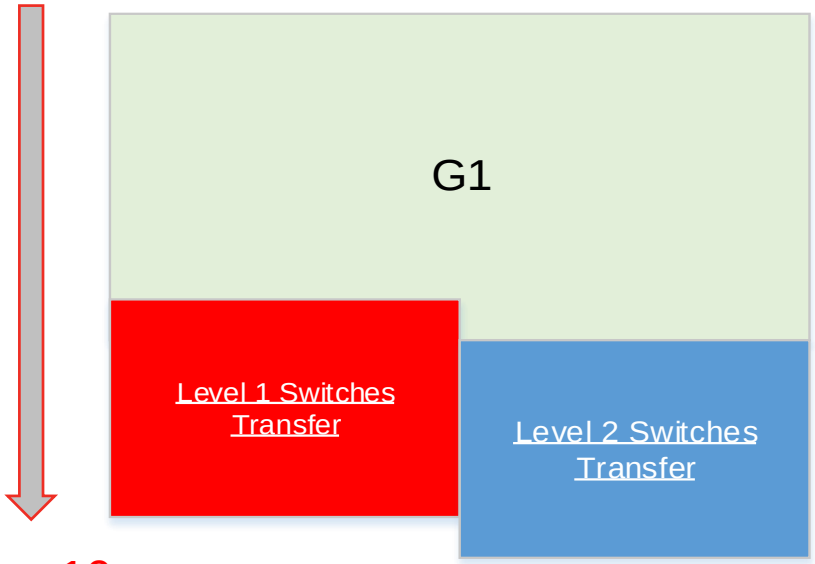
FIGURE B.1(a) Typical Rotating Emergency Power Supply System.

Reference: NFPA 110 Edition 2016, ANNEX B, Diagrams of Typical Systems

Utility Outage with Single Generator Set System – Sequence of Events

ATS control detects utility outage (1)
Time delay to start (2)
ATS sends a start signal to the generator set (3)
Generator Set Engine Crank Initiated (4)
Prime mover starts (5)
Generator set “Ready-to-Load (RTL)” (6)

Transfer time delay (7)
ATS disconnects utility (8)
ATS connects load to generator set (9)



Time = 10 s

Time Delay on Start

- Prevents nuisance starts and possible subsequent load
  - Utility recloser circuits

6.2.5* Time Delay on Starting of EPS. A time-delay device shall be provided to delay starting of the EPS. The timer shall prevent nuisance starting of the EPS and possible subsequent load transfer in the event of harmless momentary power dips and interruptions of the primary source.

A.6.2.5 For most applications, a nominal delay of 1 second is adequate. The time delay should be short enough so that the generator can start and be on line within the time specified for the type classification.

Starting System Considerations

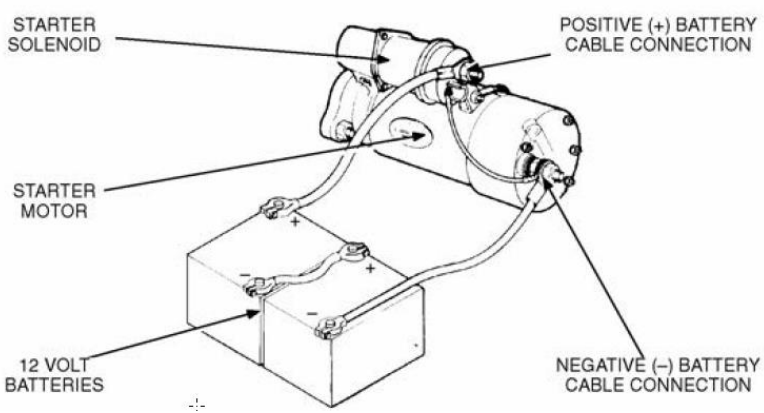
- Electric starter or a stored energy starting system allowed
- Electric starters become less effective as the temperature drops
  - loss of battery discharge capacity
  - increase in an engine's resistance to cranking under those conditions
- Air starters may increase or decrease cranking speeds affecting the overall start time
  - The air system must supply the required air volume and maintain a minimum pressure
  - Consult generator set engine manufacturer for:
    - Air hose size
    - Maximum starter pressure ratings

Starter Battery Considerations

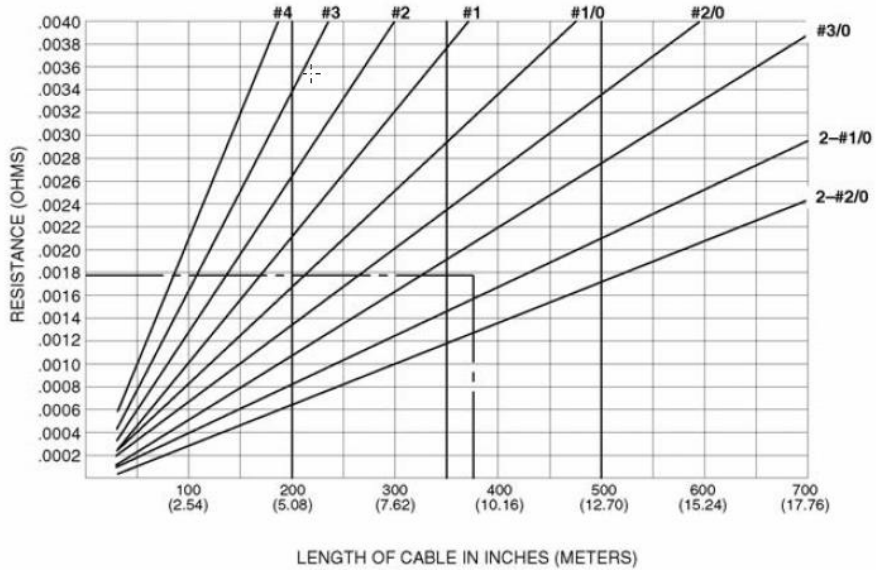
- Properly sized batteries
  - Batteries must store and discharge sufficient power to crank the engine long enough and fast enough to start the engine.
  - The batteries must be designated for this use and may have to be approved by the AHJ
- Battery shall be of the nickel-cadmium or lead-acid type
- Ambient temperatures drastically affect battery performance and charging efficiencies
  - Utilize battery heaters in cold climates
- Keep connections tight and greased to prevent corrosion

Relocating Batteries

- If standard cables are not used, new cables must be designed accordingly
- Must not result in excessive voltage drop between battery and starter motor
- Total cranking circuit resistance, cables plus connections, not to exceed:
  - 0.00075 ohms for 12V systems
  - 0.002 ohms for 24V systems



Typical electric starter motor connections (24V system shown)



Resistance vs. length for various AWG cables sizes

Starting Equipment Requirements

Table 5.6.4.2 Starting Equipment Requirements

	Starting Equipment Requirements	Level 1	Level 2
(a)	Battery unit	X	X
(b)	Battery certification	X	NA
(c)	Cycle cranking	X or O	O
(d)	Cranking limiter time-outs		
	Cycle crank (3 cycles)	75 sec	75 sec
	Continuous crank	45 sec	45 sec
(e)	Float-type battery charger	X	X
	dc ammeter	X	X
	dc voltmeter	X	X
(f)	Recharge time	24 hr	36 hr
(g)	Low battery voltage alarm contacts	X	X

X: Required. O: Optional. NA: Not applicable.

Critical Charger Performance

- Sufficient capacity to recharge batteries within 24 hours (Level 1)
  - 225 amp-hour battery recharges in 22.5 hours with 10A charger
    - Charger designed to charge a fully discharged battery
    - Typically need TWO 10A chargers for most 24V diesels
- Critical to get charger that properly “floats” when battery is fully charged.
- Proper charge rate depends on temperature compensation - especially for outdoor generator sets.
  - Battery charging voltages should be corrected based on battery temperature
  - Automatic temperature compensation - target charge voltages change based on battery temperature
- Use a redundant/back-up battery charger to ensure fully charged batteries.

Starter Battery Considerations – Lead Acid vs. NiCd

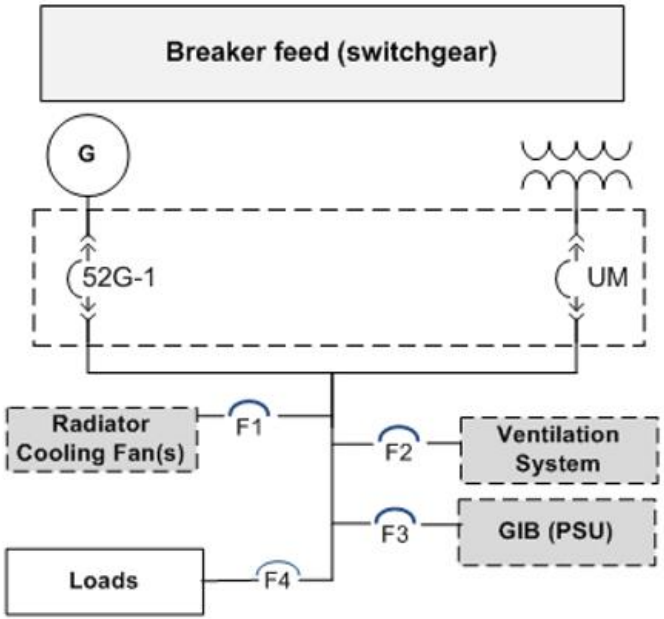
Battery type	Charge temperature	Discharge temperature	Charge advisory
Lead acid	–20°C to 50°C (–4°F to 122°F)	–20°C to 50°C (–4°F to 122°F)	Charge at 0.3C or lessbelow freezing. Lower V-threshold by 3mV/°C when hot.
NiCd	0°C to 45°C (32°F to 113°F)	–20°C to 65°C (–4°F to 149°F)	Charge at 0.1C between –18°C and 0°C. Charge at 0.3C between 0°C and 5°C. Charge acceptance at 45°C is 70%. Charge acceptance at 60°C is 45%.

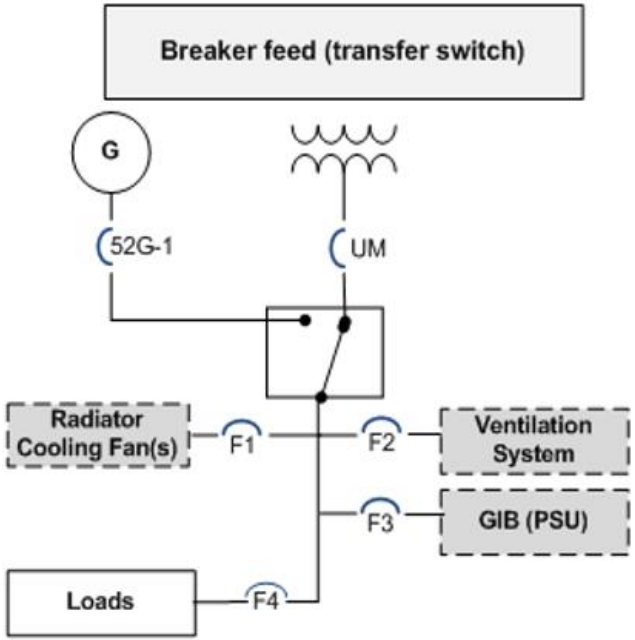
Reference: BatteryUniversity.com - **BU-410: Charging at High and Low Temperatures**

Controlling Engine Inertia Load

- More inertia load on the engine may increase engine start time
- Pay attention to the generator set configuration
  - Unnecessarily oversized alternator = larger rotational inertia
  - Medium voltage alternator = larger rotational inertia
- Pay attention to cooling package requirements
  - Larger mechanically driven radiators = additional inertia
  - For larger generator sets consider remote electric radiators
    - Add electric loads for the remote radiator fan, ventilation fans, coolant pumps and other accessories to the total load requirement of the generator set.
- Watch out for “boilerplate” specification language!

Traditional Recommended Auxiliary Equipment Electrical Connections for Standby Operation





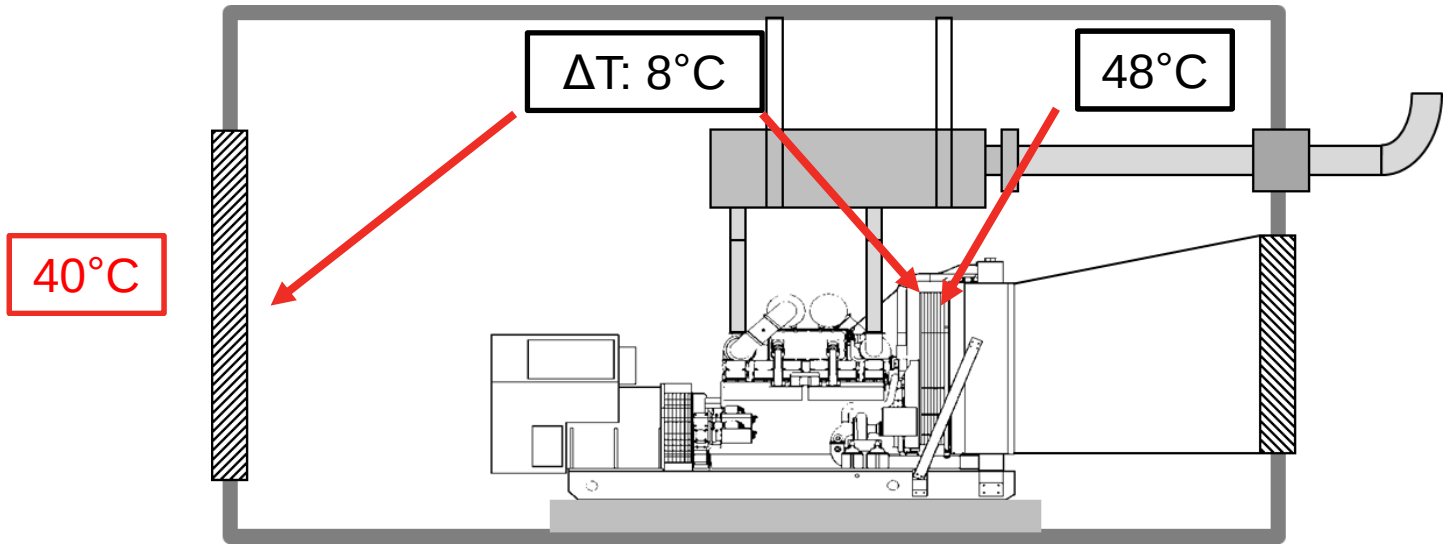
Caveat – additional complexity and points of failure

Engine Cooling Systems

5.6.7.3 Cooling systems shall prevent overheating of prime movers under conditions of highest anticipated ambient temperature at the installed elevation (above sea level) when fully loaded.

- Industry standards 40°C / 50°C
- Generator set power output may need to be reduced at high ambient conditions.
- Ambient rating vs. Air-on-Core ratings
- Verifying 5.6.7.3 with Air-on-Core ratings may be more challenging

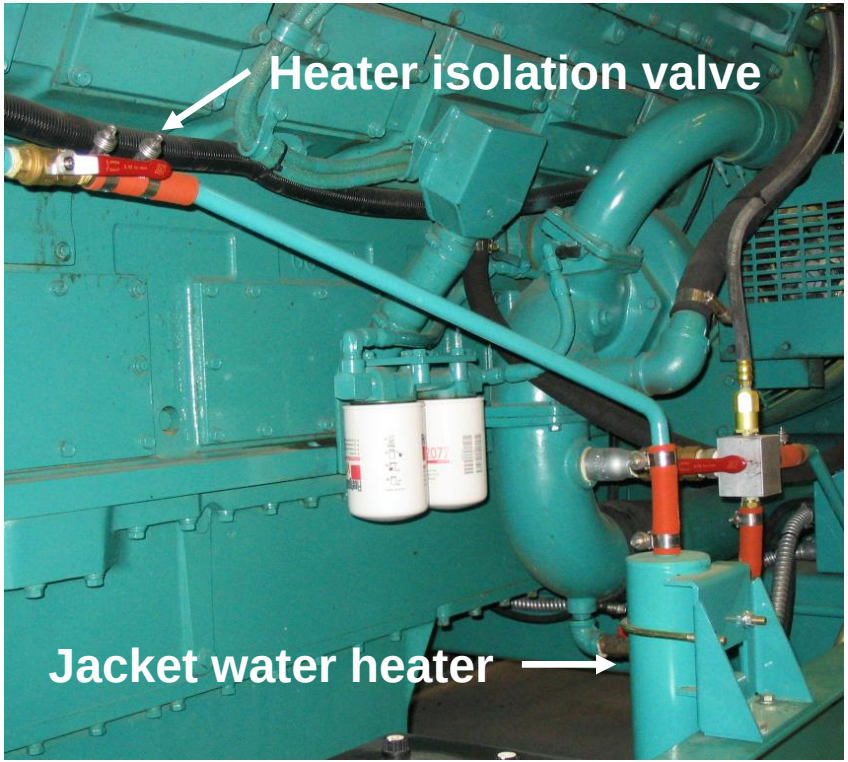
Cooling System Ratings



- Ambient: 40°C ≈ 48°C Air-on-Core
- Air-on-Core: 40°C ≈ 32°C Ambient
- Verifying 5.6.7.3 is more challenging – what is ΔT?
- Put the responsibility on the generator set manufacturer

Energy Converters — Temperature Maintenance.

- **5.3.1** The EPS shall be heated as necessary to maintain the water jacket and battery temperature determined by the EPS manufacturer for cold start and load acceptance for the type of EPSS.
- **5.3.5** The ambient air temperature in the EPS equipment room or outdoor housing containing Level I rotating equipment shall be not less than 4.5°C (40°F).
- **7.7.6** Units housed outdoors shall be heated as specified in 5.3.5.



Temperature Maintenance – Key Points

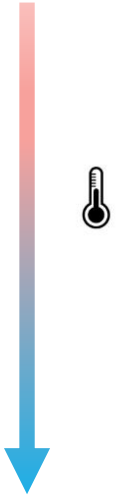
- Coolant heater not designed to heat the area around the generator set!
- Failure of the water jacket heater or reduction of the ambient temperature around the engine may affect engine start time and load acceptance time
- Low engine temperature alarm functions are commonly added to generator sets to alert operator to this potential system-operating problem.
- Manufacturers may design and evaluate EPS cold start performance based on these criteria
- Verify before cold start test during site commissioning of the system

Fuel System Design Considerations

- **7.9.1.2*** Fuel system design shall provide for a supply of clean fuel to the prime mover.
- Regularly scheduled surveillance of the fuel – avoid “stale” fuel issues
- Begin maintenance and testing the day of installation and first fill → establish a benchmark guideline for future comparison.
- Laboratory testing services should always be sought from a qualified or certified petroleum laboratory.
- Ensure fuel filters are clean
  - Air filters too
- Air in the fuel system acts as an air lock - prevents normal supply of fuel to cylinder.

Fuel Types: Diesel and Cold Weather

- High diesel fuel viscosity
  - Increase fuel system restriction
  - Inability to maintain required fuel pressure
- Cloud point (≤ 15°F)
  - Wax particles starts to form
  - Fuel filter plug point (clogging)
  - Measure (1) ✓
- Pour point (≤ 0°F)
  - Fuel too viscous to flow
  - Measures (1) and (2) ✓

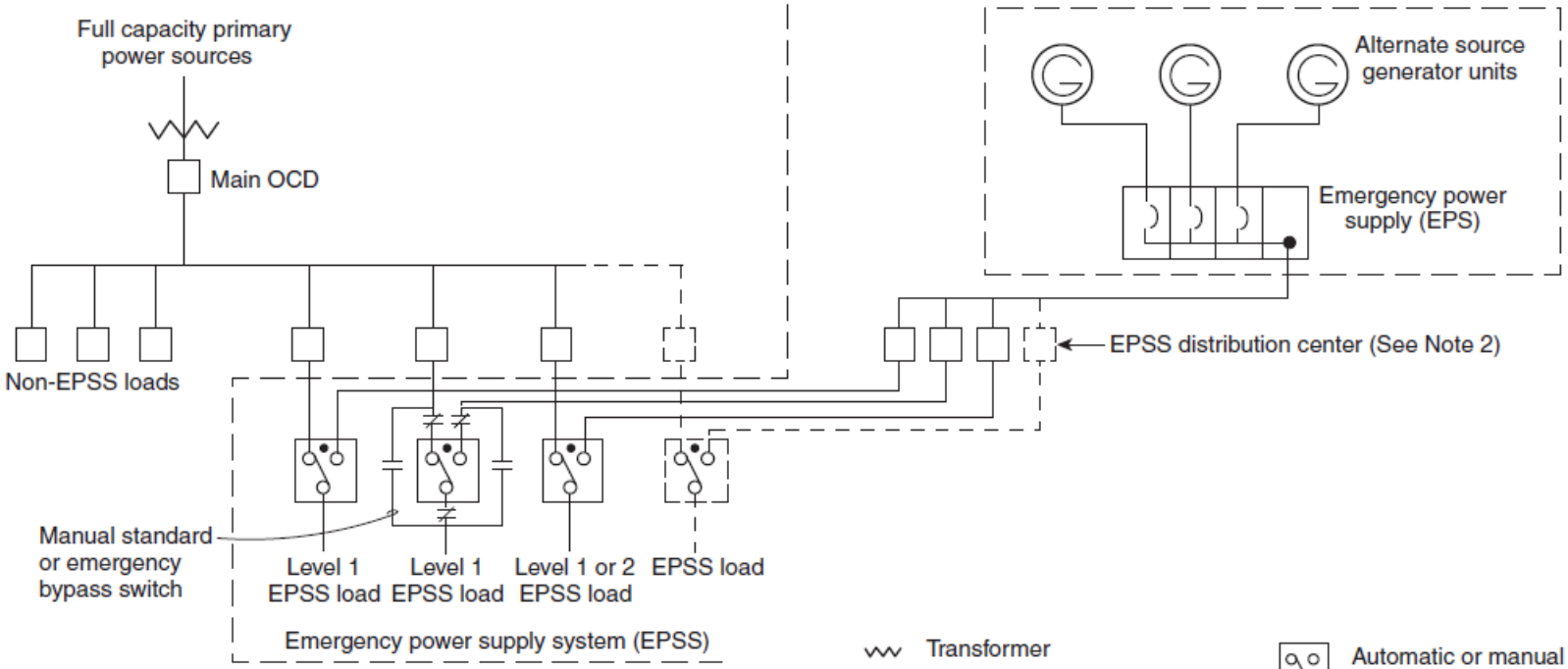


Mitigation measures:

(1) Heaters
- Filters
- Tank
- Fuel lines

(2) Blending
- Additives
- Blend Diesel #1 with #2

Multiple Generator Set EPSS



Notes:
1. One alternate source generator unit of the paralleling system to have sufficient capacity to carry all required Level 1 loads.
2. The EPSS distribution center can be installed in additional cubicles as part of the paralleling board setup.

FIGURE B.1(b) Typical Multiple-Unit Emergency Power Supply System.

Reference: NFPA 110 Edition 2016, ANNEX B, Diagrams of Typical Systems

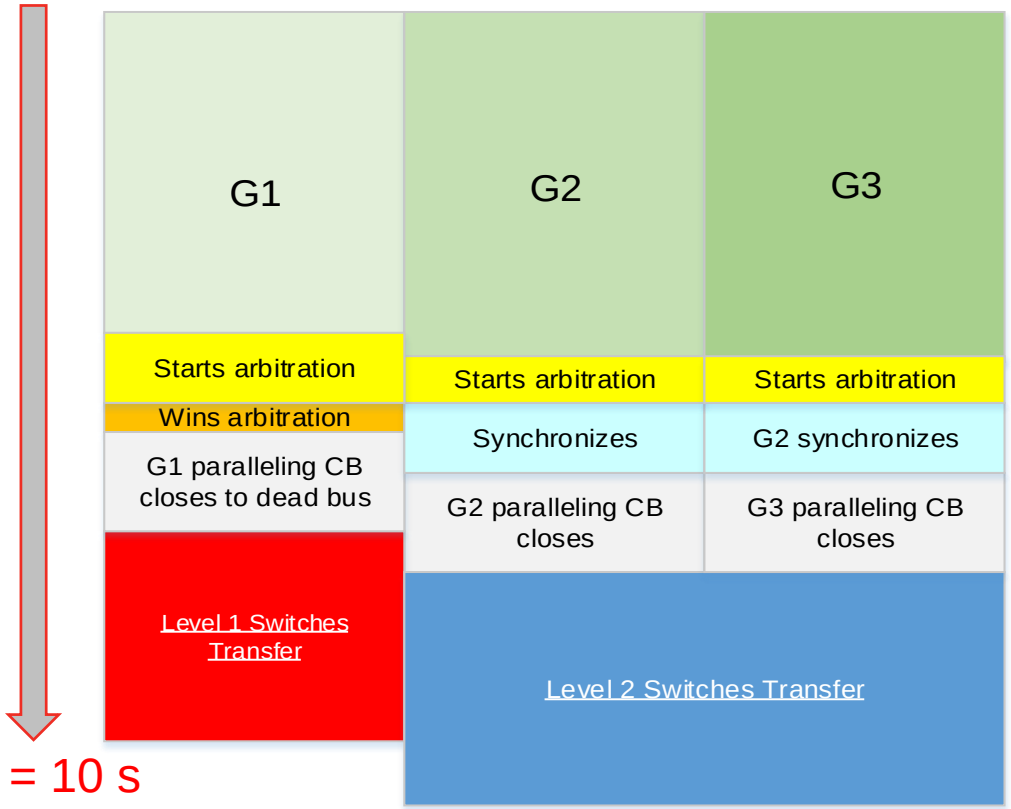
Utility Outage with Multiple Generator Set System – Sequence of Events

ATS control detects utility outage (1)
Time delay to start (2)
ATS sends a start signal to the generator set (3)
Generator Set Engine Crank Initiated (4)
Prime mover starts (5)
Generator set “Ready-to-Load (RTL)” (6)
First start arbitration process begins (7)

Synchronizing time (8)

CB closure time (9)

Transfer time delay (10)
ATS disconnects utility (11)
ATS connects load (12)



Multiple Generator Sets Paralleling - First Start Arbitration and Synchronization

- First start arbitration between the generators determines which one is allowed to close first to a dead bus
  - Takes anywhere from 0.7 seconds up to 2 seconds
- Time to synchronize the remaining generators to paralleling bus
  - Depends in part on how much their phase angles differ from the phase angle of the connected generator
  - Phase angle difference is an uncontrolled variable
  - Adding load before all the generators are paralleled can slow down the synchronizing stage
- Motorized paralleling circuit breakers closing time almost negligible (5 cycles)

Conclusion

- Remember: Type and Class requirements apply to the EPSS and not the EPS!
- Performance specifications should be written around the system
- Advantage of working with a single-source manufacturer of complete power system:
  - Can allow seamless integration of power system technology comprising generator sets, generator set controls, automatic transfer switches, switchgear, digital paralleling and networking
  - Components designed and built to work together
  - "One throat to choke"

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Bonus Information

Time Delay on Transfer to EPS

- **6.2.7 Time Delay on Transfer to EPS.** An adjustable time-delay device shall be provided to delay transfer and sequence load transfer to the EPS to avoid excessive voltage drop when the transfer switch is installed for Level 1 use.

Considerations for Gaseous Fuel Systems: Natural Gas

- Quality: Utility grade natural gas
  - Variations of ‘field gas’ or international markets may require composition analysis
- Volume: Check generator set datasheet requirements
  - Piping based on consumption
- Pressure: Typically 7” to 14” water column at generator set
  - Ensure utility pressure is sufficient
  - Be aware of transient loading impacts on utility distribution
- AHJ Might not except NG generator set – on-site fuel storage requirements
  - Duel Fuel – LPG/NG with Auto-changeover
  - On-site LP sized to meet class requirements.

Meeting Class and Fuel Storage Requirements

- 7.9.5 Integral tanks of the following capacities shall be permitted inside or on roofs of structures, or as approved by the authority having jurisdiction:
  - (1) Maximum of 2498 L (660 gal) diesel fuel
  - (2) Maximum of 95 L (25 gal) gasoline fuel
- What is the AHJ's interpretation on this?

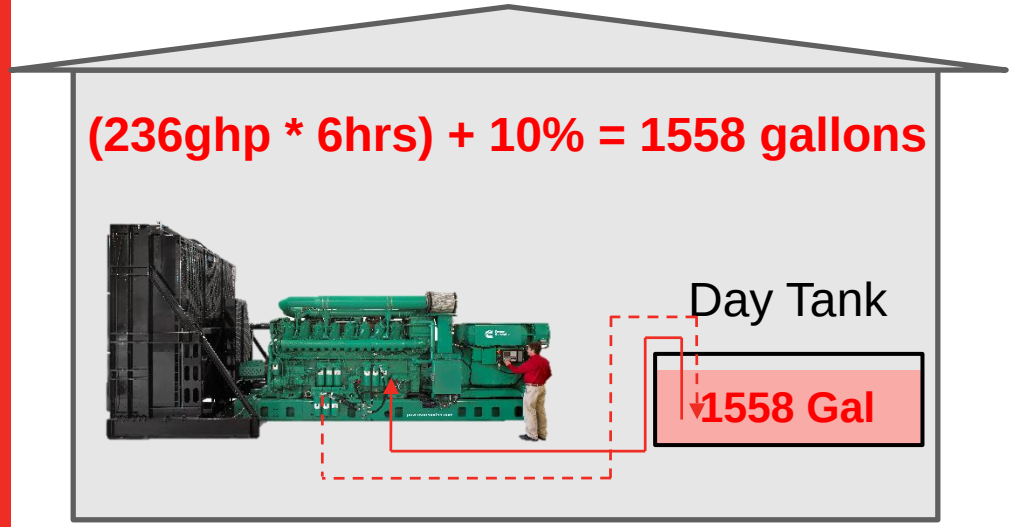
Tank Sizing Example

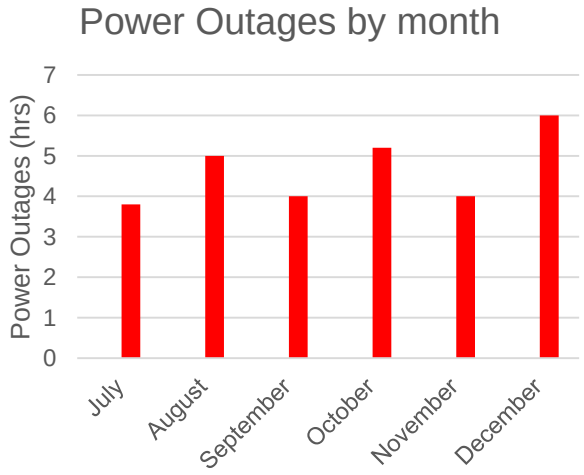
You are required to size a fuel diesel tank for a C3500 D6e installed inside a building with the following requirements:

- Standby application
- Outage duration
- Rule of thumb plus 10%
- NFPA 110 (max. of 660 gal inside a building)

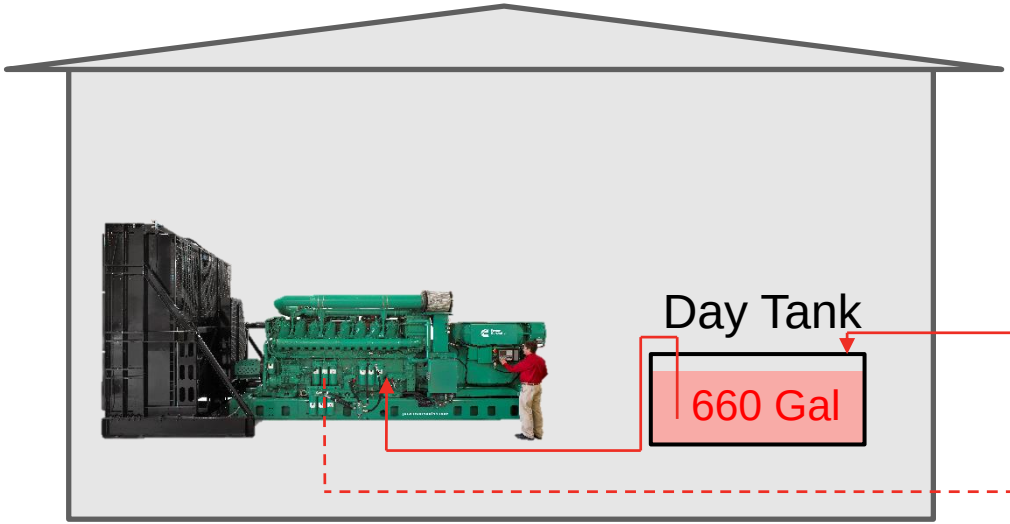
C3500 D6e

Fuel consumption	**Standby**			
	kW (kVA)			
Ratings	3500 (4375)			
Ratings without fan[1]	3606 (4508)			
Load	**1/4**	**1/2**	**3/4**	**Full**
US gph	77	130	183	236
L/hr	291	492	693	893





Bonus Information - Tank Sizing Example



Supply Line

Return Line

Bulk Tank

898 Gal

5,004 Gal

10,668 Gal

- NFPA 110 (660 gallons) → 1,558 Gal
- 24 hours → 5,664 Gal
- 48 hours → 11,328 Gal

Bonus Information - Minimum Start Time Delay for Testing Purposes

- 8.4.5 *does* require a minimum 1 second delay on start for monthly testing purposes
- Criteria set forth in section 4.3 and in Table 4.1 (b) shall not be required during monthly testing of the EPSS
- 8.4.6.2: If start time requirement is not demonstrated during the monthly testing then a process should exist so that the systems can be show to meet the 10 second start one per year

Q&A

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