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Understanding ISO 8528
Generator Set Ratings

July 18th, 2017 11:00 PDT / 13:00 CDT
(1PDH issued by Cummins)
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Course Objectives

Participants will be able to:

- Describe generator set ratings definitions per the ISO 8528-1.
- Identify appropriate usage of industry-adopted ratings.
- Recognize alternator thermal ratings and appropriate selection considerations.
Generator Set Data Sheet

Model: C3500 D6e
Frequency: 60 Hz
Fuel type: Diesel
kW rating: 3500 standby
3000 prime
2750 continuous
Emissions level: EPA NSPS Stationary Emergency Tier 2

<table>
<thead>
<tr>
<th>Fuel consumption</th>
<th>Standby kW (kVA)</th>
<th>Prime kW (kVA)</th>
<th>Continuous kW (kVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating</td>
<td>3500</td>
<td>3000</td>
<td>2750</td>
</tr>
<tr>
<td>Rating without fan*</td>
<td>3500 (4750)</td>
<td>3000 (4750)</td>
<td>2750 (4539)</td>
</tr>
<tr>
<td>Load</td>
<td>1/4</td>
<td>1/2</td>
<td>3/4</td>
</tr>
<tr>
<td>US gph</td>
<td>77</td>
<td>130</td>
<td>193</td>
</tr>
<tr>
<td>Ltr</td>
<td>291</td>
<td>460</td>
<td>663</td>
</tr>
</tbody>
</table>

*Ratings for reference with the optional remote cooling configuration. See note 1 under “Alternate data” section.

**Engine**

- **Engine model**: C3500 D6e
- **Cylinders**: 6
- **Displacement**: 19.9 L
- **Main bearing caps**: 8
- **Engine speed**: 1800 rpm
- **Fuel system**: Electronic fuel injection
- **Starting system**: 12V DC electric

<table>
<thead>
<tr>
<th>Engine</th>
<th>Standby rating</th>
<th>Prime rating</th>
<th>Continuous rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>3500 (4750)</td>
<td>3000 (4750)</td>
<td>2750 (4539)</td>
</tr>
<tr>
<td>BMEP at rated load</td>
<td>2254 (3382)</td>
<td>2218 (3327)</td>
<td>2058 (3000)</td>
</tr>
<tr>
<td>Stroke, mm (in)</td>
<td>180 (7.1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fuel flow**

- **Maximum fuel flow, L/hr (US gph)**: 1401.1 (423)
- **Maximum fuel filter restriction, kPa (inHg)**: 13.5 (449)
- **Maximum fuel return line restriction, kPa (inHg)**: 3.4 (0.1)
- **Maximum fuel inlet temperature, °C (°F)**: 60.1 (140)
- **Maximum fuel outlet temperature, °C (°F)**: 82.2 (182)

<table>
<thead>
<tr>
<th>Air</th>
<th>Standby (kW)</th>
<th>Prime (kW)</th>
<th>Continuous (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion air, m³/min (scf/Min)</td>
<td>251 (9003)</td>
<td>270 (9550)</td>
<td>285 (9970)</td>
</tr>
<tr>
<td>Excess airflow at cold 100% load</td>
<td>477 (168)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exhaust</th>
<th>Standby (kW)</th>
<th>Prime (kW)</th>
<th>Continuous (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust flow at rated load, m³/min (std)</td>
<td>726 (2504)</td>
<td>641 (2294)</td>
<td>608 (2152)</td>
</tr>
<tr>
<td>Exhaust temperature at rated load, °C (°F)</td>
<td>430 (814)</td>
<td>441 (825)</td>
<td>417 (713)</td>
</tr>
<tr>
<td>Maximum back pressure, kPa (inHg)</td>
<td>7.2 (28)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Industry Standard for Generator Set Ratings

- ISO 8528: Standard for reciprocating internal combustion engine driven alternating current generator sets.
- Defines application, ratings and performance of generator sets.
- Sect. 13 defines these ratings:
  - Emergency Standby Power (ESP)
  - Limited Time Prime Power (LTP)
  - Prime Rated Power (PRP)
  - Continuous Operating Power (COP)
- Any manufacturer can go above and beyond the ISO ratings definitions.
  - Data Center Continuous (DCC)
Factors Affecting Choice of Generator Set Rating

- Annual Generator Set Run Time
- Applied Load (Variable or Constant)
- Negotiated Contracts (Rate Curtailment Programs)
- Warranty
Emergency Standby Power (ESP)

- For supplying emergency power for the duration of a utility power failure
- Not to exceed 200 hrs/yr
- Average load factor of 70% of the standby rating over 24 hour period
- No negotiated outage operations

\[ P_{pa} = \frac{P_1 t_1 + P_2 t_2 + P_3 t_3 + \cdots + P_n t_n}{t_1 + t_2 + t_3 + \cdots + t_n} = \frac{\sum_{i=1}^{n} P_i t_i}{\sum_{i=1}^{n} t_i} \]

\( t_1 + t_2 + t_3 + \cdots + t_n = 24 \text{ hours} \)
Example ESP Applications

- Emergency (such as backup to Life Safety, legally required or critical loads)
- Optional Standby (not required by the Authority Having Jurisdiction, but desired to minimize economic losses or equipment damages at a site due to utility power interruptions)

Application:
Fully Integrated standby power system containing 7 Cummins C2000D6 (2000 kWe) generator sets individually controlled and paralleled with PCC3201

Location:
Samsung SDS Institute in Suwon, South Korea

Application:
2 x Cummins DQGAA (1250 kWe)
1 x Cummins DQGAB (1500 kWe)

Location:
Intermountain Healthcare Facility in Salt Lake City, UT

Application:
Fully Integrated standby power system containing 7 Cummins C2000D6 (2000 kWe) generator sets individually controlled and paralleled with PCC3201

Location:
Samsung SDS Institute in Suwon, South Korea
Limited Time Prime Power (LTP)

- **Limited number of hours**: 500 hr/year
- **Non-Variable Load**
- Applications not to exceed 100% of the Prime Power rating **(no Overload is permitted)**
- Any operation exceeding 500 hours per year should use the Continuous Power Rating

Diagram:
- Time: $t_1$
- Power: $t_1$
- Shutdown for maintenance
- 500 hr/yr max
- 1 Year
Examples of LTP Applications

- Base Loading
- Rate Curtailment

Application:
9 x Cummins C2000 D6
(2000 kWe ISO LTP)

Location:
Santo Domingo, Dominican Republic
Prime Rated Power (PRP)

- Unlimited number of hours per year (8760 hr/yr less service)
- Variable load
- Not to exceed 70% average of the Prime rating during any operating period of 24 hours

24 Hours/365 days a year

$$P_{pa} = \frac{P_1 t_1 + P_2 t_2 + P_3 t_3 + \cdots + P_n t_n}{t_1 + t_2 + t_3 + \cdots + t_n} = \frac{\sum_{i=1}^{n} P_i t_i}{\sum_{i=1}^{n} t_i}$$
Examples of PRP Applications

- Applications that use on-site generation in lieu of a utility electricity supply, typically where utility power is not available.
- Peak shaving and rate curtailment.

**Application:**
500kVA generator powers the dockside rubber tyred gantry cranes.

Cranes lift capacity is 88 tons and can move at 440 feet per minute.
Continuous Operating Power (COP)

- Unlimited number of hours per year (8760 hr/yr less service)
- Applicable for supplying utility power at a constant 100% load for an unlimited number of hours per year.
- No overload capability is available for this rating.
Examples of COP Applications

- The COP Rating Genset is generally used when paralleled to the utility
- Base Loading
- Combined Heat and Power (CHP)
Industry-Adopted Ratings
The tier rating system is the industry standard for benchmarking data center reliability.

Four tiers, each building on requirement to the one below (ex. Tier II requires all of Tier I capability, plus the added requirements).

Power Generation and distribution is one of 16 subsystems evaluated.

No fractional tier ratings.

Tiers do not specify certain equipment, but rather a level of redundancy and security to maximize run time.

To be an enterprise class data center, UPS and generator sets are required equipment.

Significant costs associated with higher tier rating.
Generator Sets for Tier III or Tier IV Systems

- “Disruptions to the utility power are not considered a failure but an operational condition for which the site must be prepared”
- “A Tier III or Tier IV engine-generator system, along with its power paths and other supporting elements shall meet … performance confirmation tests while they are carrying the site on engine-generator power”
- “Engine-generators for Tier III and Tier IV sites shall not have a limitation on consecutive hours of operation when loaded to ‘N’ demand”
Data Center Continuous Ratings

- Data Center Continuous (DCC) Ratings meet the Uptime Institute Tier III and Tier IV requirements.
- Data Center Continuous (DCC) Rating is defined as:
  
  *The maximum power which the generator is capable of delivering continuously to a constant or varying electrical load for unlimited hours in a data center application.*

  “… where a reliable utility power is available…”

For more details, watch out for upcoming PowerHours, Generator Ratings for Data Centers and Generator Set Features for Data Centers!
Rating Example – Generator Set Model DQLF

Generator Set Power, kWe

- **ESP**: Full Rating 2750, Max 24 Hour Avg. 1925
- **PRP**: Full Rating 2500, Max 24 Hour Avg. 1750
- **LTP**: Full Rating 2500, Max 24 Hour Avg. 2100
- **COP**: Full Rating 2500, Max 24 Hour Avg. 2100
- **DCC**: Full Rating 2500, Max 24 Hour Avg. 2500

200 Hrs/yr, 500 Hrs/yr
Generator Set Rating Example

- **Emergency Standby Power rating** 2750 kW
  - Max avg. load in 24h period (70%): 1925 kW
  - 200h/year

- **Prime Rated Power rating** 2500 kW
  - Max avg. load in 24h period (70%): 1750 kW

- **Limited Time Prime Power rating** 2500 kW
  - Max avg. load in 24h period (100%): 2500 kW
  - 500h/year with non-variable load

- **Continuous Operating Power** 2100 kW
  - Max avg. load in 24h period (100%): 2100 kW

- **Data Center Continuous rating** 2500 kW
  - Max avg. load in 24h period (100%): 2500 kW
  - Unlimited hours in Data Center Application
Concept Check

Based on the application shown, which ISO 8528-1 generator set rating should be selected?

a) Emergency Standby Power
b) Prime Rated Power
c) Limited Time Prime Power
d) Continuous Operating Power
Generator Set Ratings Watch-Outs

- Parasitic losses
  - Not all generator set manufacturers publish ratings that include all parasitic losses such as cooling systems.

  Published Rating: 3350 kWe
  Parasitic Losses: 100 kWe
  Actual Available Customer Load: 3250 kWe

- Site impact on ratings
  - Altitude and ambient conditions may impact available customer load.
  - Generator set manufacturers adopt a wide variety of “standard” conditions.
Altitude Impact

- Manufacturer A: 2750 kWe (no derate)
- Manufacturer B: 2200 kWe (20% derate)
EPA Usage Categories
EPA Product Use Definitions

- EPA definitions are NOT the same as ISO8528-1
- EPA definitions are determined by actual product use and engine horsepower:

  - Stationary (40 CFR Part 60)
    - Stationary Emergency
    - Stationary Non-Emergency
  - Nonroad CI (40 CFR Part 89)
    - No emergency provision in non-road rules
  - Nonroad SI (40 CFR Part 1048)
    - No emergency provision in non-road rules

- Emissions are most stringent for non-road and stationary non-emergency, compared to stationary emergency
- Codes and details found on EPA website
  - http://www.epa.gov/ttn/atw/icengines
Concept Check

You are the owner of a new facility that requires generator sets for the sole purpose of providing emergency backup power for the utility. The annual utility outage expected is around 20 hrs/year with a variable load profile.

Which ISO 8528-1 Generator Set rating/EPA Exhaust Emissions designation should you select?

a) Emergency Standby Power/Stationary Non-Emergency
b) Prime Rated Power/Stationary Non-Emergency
c) Emergency Standby Power/Stationary Emergency
d) Continuous Operating Power/Stationary Non-Emergency
Alternator Ratings
Several generator set models may be based on the same engine platform.

In turn, each generator set is typically offered with multiple ratings options as discussed previously.

Each generator set rating may be offered with multiple alternator options with varying voltage options.
Generator Set Alternator Options and Ratings – Example

60Hz Diesel Model: C3500 D6e
- Standby: 3500 kWe
- Prime: 3000 kWe
- Continuous: 2750 kWe

AvK DIG-HV
- DIG142c - 3398 kW
- DIG142d - 3644 kW
- DIG142f - 4299 kW

STAMFORD P80-HV
- HVSI804W - 3032 kW
- HVSI804X - 3436 kW
Generator Set Alternator Ratings Definitions

- **Insulation Class**
  - Maximum operation temperature allowed by the insulation material in the winding
    - Class F (155°C) and Class H (180°C)
  - Defined by international standard (NEMA, UL, IEC)

- **Temperature Rise Class/Ratings**
  - Temperature rise allowed over an ambient temperature
  - Depends on the application
    - Standby or Continuous

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>80</td>
<td>130</td>
</tr>
<tr>
<td>F</td>
<td>105</td>
<td>155</td>
</tr>
<tr>
<td>H</td>
<td>125</td>
<td>180</td>
</tr>
</tbody>
</table>
### Generator Set Alternator Ratings

<table>
<thead>
<tr>
<th></th>
<th>3 Ø RATINGS (0.8 power factor)</th>
<th>60 Hz (winding no)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Based on specific temperature rise at 40°C ambient temperature)</td>
<td>416 (12)</td>
</tr>
<tr>
<td>163°C Rise Ratings</td>
<td>kW 2288 2420 2640 2640 2640 2640</td>
<td>kVA 2860 3025 3300 3300 3300</td>
</tr>
<tr>
<td></td>
<td>kW 2224 2352 2560 2560 2560</td>
<td>kVA 2780 2940 3200 3200 3200</td>
</tr>
<tr>
<td>125°C Rise Ratings</td>
<td>kW 2080 2200 2400 2400 2400</td>
<td>kVA 2600 2750 3000 3000 3000</td>
</tr>
<tr>
<td>105°C Rise Ratings</td>
<td>kW 1908 2016 2200 2200 2200</td>
<td>kVA 2385 2520 2750 2750 2750</td>
</tr>
<tr>
<td>80°C Rise Ratings</td>
<td>kW 1664 1760 1920 1920 1920</td>
<td>kVA 2080 2200 2400 2400 2400</td>
</tr>
</tbody>
</table>
# Generator Set Ratings

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Type</td>
<td>Variable</td>
<td>Constant</td>
<td>Variable</td>
<td>Constant</td>
</tr>
<tr>
<td>Annual operating hours</td>
<td>200</td>
<td>500</td>
<td>Unlimited</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Average load</td>
<td>70%</td>
<td>100%</td>
<td>70%</td>
<td>100%</td>
</tr>
<tr>
<td>Overload</td>
<td>No</td>
<td>No</td>
<td>10% (1 hr/12 hrs, 25 hrs/year)*</td>
<td>No</td>
</tr>
<tr>
<td>Max. Alternator Rating (NEMA MG1-32)</td>
<td>Standby</td>
<td>Standby</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>Max. Alternator Ratings</td>
<td>Class H Standby 150/40</td>
<td>Class H Standby 150/40</td>
<td>Class H 125/40</td>
<td>Class H 125/40</td>
</tr>
<tr>
<td></td>
<td>Standby 163/27</td>
<td>Standby 163/27</td>
<td>Class F 105/40</td>
<td>Class F 105/40</td>
</tr>
<tr>
<td></td>
<td>Class F</td>
<td>Class F</td>
<td>Class B 80/40</td>
<td>Class B 80/40</td>
</tr>
<tr>
<td></td>
<td>Standby 125/40</td>
<td>Standby 125/40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*May vary based on generator set manufacturer.
Summary

- Select correct Generator set rating based on intended use, load profile and hours of operation.
- ISO 8528-1 defines industry standard generator set ratings, industry-adopted ratings may go above and beyond ISO 8528-1.
- EPA ratings are not to be confused with ISO8528-1 generator set ratings.
- Thermal ratings are directly correlated to insulation half life and may impact other power system characteristics.
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