Specifying Gaseous Generator Sets

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Disclaimer

The views and opinions expressed in this course shall not be considered the official position of any regulatory organization 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. In addition, when in doubt, reach out to the Authority Having Jurisdiction.
Course Objectives

Specifying Gaseous Generator Sets

This course will provide an overview of gaseous generator set capabilities in different applications. Participants will be able to recognize similarities between diesel and gaseous generator sets and describe gaseous generator sets features and considerations for planning projects and installation.

After completing this course, participants will be able to:

- Recognize the similarities and distinctions between gaseous and diesel generator sets
- Describe key features and capabilities of gaseous generator sets
- List some key considerations for gaseous generator sets installation
Diesel Fuel Vs Gaseous Fuel

- Diesel Fuel is power dense
  - High energy content
  - Most commonly used in generator sets is Diesel #2 ASTM D975

- Gaseous Fuel is variable
  - Depending on the location
  - Most common is Pipeline Natural Gas

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Energy Content [Btu]</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>950-1150</td>
<td>1 ft³</td>
</tr>
<tr>
<td>Propane gas</td>
<td>2250</td>
<td>1 ft³</td>
</tr>
<tr>
<td>Propane Liquid Gas</td>
<td>91330</td>
<td>1 Gallon</td>
</tr>
<tr>
<td>Gasoline</td>
<td>124000</td>
<td>1 Gallon</td>
</tr>
<tr>
<td>Diesel Fuel</td>
<td>139000</td>
<td>1 Gallon</td>
</tr>
</tbody>
</table>
## What is Gaseous Fuel?

<table>
<thead>
<tr>
<th>Category</th>
<th>Also Known As</th>
<th>BTU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional Natural Gas</strong></td>
<td>Pipeline Gas, Standard Gas</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Associated Petroleum Gas (APG)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Flare Gas, Field Gas</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Associated-Dissolved Gas (ADG)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Wellhead Gas</td>
<td>High</td>
</tr>
<tr>
<td><strong>Unconventional Natural Gas</strong></td>
<td>Coal Bed Methane (CBM)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Coal Mine Methane (CMM)</td>
<td>~Low</td>
</tr>
<tr>
<td><strong>Biogas</strong></td>
<td>Anaerobic Digester Gas (ADG)</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Wastewater Treatment Plant Gas</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Syngas</strong></td>
<td>Synthesis Gas, Pyrolysis Gas</td>
<td>Very Low</td>
</tr>
<tr>
<td><strong>Industrial Gas</strong></td>
<td>Town Gas</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

**Spec Note** Specify which fuel type is present on site
Methane Number of Various Fuels

- Methane Index Number (MN) defines likelihood of a fuel to auto-ignite
  - Scale of 0-100
  - Higher MN less likely for fuel to auto-ignite (knock)
  - Lower MN may require power derate and/or timing changes
- High quality pipeline NG 80-90 MN

**Methane number capability table B**

<table>
<thead>
<tr>
<th>Load (percent of rated)</th>
<th>100%</th>
<th>90%</th>
<th>75%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>62</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

**Spec Note** Include fuel composition when discussing with generator set manufacturer
## Gaseous Generator Sets Types

<table>
<thead>
<tr>
<th></th>
<th>Rich Burn</th>
<th>Lean Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Fuel Ratio</strong></td>
<td>~14.6 : 1</td>
<td>~25 : 1</td>
</tr>
<tr>
<td><strong>Excess Air (O₂)</strong></td>
<td>0.2 to 0.8%</td>
<td>&gt;4%</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Fast start and can accept large block loads</td>
<td>High efficiency but requires advanced controls</td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td>Aftertreatment may be required to reduce NOx and CO</td>
<td>Can often meet emissions requirements without aftertreatment</td>
</tr>
</tbody>
</table>
Industry Standard for Generator Set Ratings

- ISO 8528: Defines application, ratings and performance of generator sets.
  - Emergency Standby Power (ESP)
  - Prime Rated Power (PRP)
  - Limited Time Prime Power (LTP)
  - Continuous Operating Power (COP)
  - Data Center Power (DCP)
- Any manufacturer can go above and beyond the ISO ratings definitions.
- ISO 8528 is a reference standard that only describes duty cycle, NOT product life.
Standby Application

**NFPA 110: Standard for Emergency and Standby Power Systems**

Level – Two levels of equipment installation, performance, and maintenance.

- **Level 1** Emergency Power Systems for emergency lighting shall be at least **Type 10**, Class 1.5, Level 1

- **Level 2** systems shall be installed where failure of the Emergency Power Supply System (EPSS) to perform is less critical to human life and safety
  - **Type 60**, Class 2, Level 2 EPSS for new mechanical ventilation

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**Table 4.1(b) Types of EPSSs**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Power Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type U</td>
<td>Basically uninterruptible (UPS systems)</td>
</tr>
<tr>
<td>Type 10</td>
<td>10 sec</td>
</tr>
<tr>
<td>Type 60</td>
<td>60 sec</td>
</tr>
<tr>
<td>Type 120</td>
<td>120 sec</td>
</tr>
<tr>
<td>Type M</td>
<td>Manual stationary or nonautomatic — no time limit</td>
</tr>
</tbody>
</table>

Reprinted with permission from NFPA 110-2016, Standard for Emergency and Standby Power Systems. Copyright © 2015, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety which can be obtained through the NFPA web site at www.nfpa.org.
Limited Time Prime Application

Demand Response

- Also referred to as peak shaving or rate curtailment
- Applications that use on-site generation in lieu of a utility electricity supply
- Some applications will request a generator set to start when asked by the utility, or when the electricity cost is predicted to increase
Exhaust Emissions

- US EPA New Source Performance Standards (NSPS) Stationary requirements
  - “Emergency” - operation when utility power is not available
  - “Non-Emergency” – operation when utility power is available

- Local authority may mandate lower values, particularly related to non-emergency usage
  - Exhaust aftertreatment may be required

Spec Note: Always consult with the local air quality board as enforced standards do vary widely by location
## Emissions Certification

### Diesel vs Gaseous Sets Emergency

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>NOx + NMHC</th>
<th>CO</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 Diesel 174 &lt; HP &lt; 751</td>
<td>4.0</td>
<td>3.5</td>
<td>0.2</td>
</tr>
<tr>
<td>NG &gt; 130 HP</td>
<td>2.0</td>
<td>4.0</td>
<td>-</td>
</tr>
</tbody>
</table>

### NOx/NMHC / CO / PM (g/kW-hr)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2-7</td>
<td>0.50</td>
<td>7.50 / 8.0 / 0.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-18</td>
<td>5 / 6 / 0.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19-36</td>
<td>29 / 30</td>
<td>7.5 / 5 / 0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37-75</td>
<td>6 / 7</td>
<td>4.7 / 5 / 0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-100</td>
<td>5 / 6 / 0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101-125</td>
<td>10 / 12</td>
<td>4.7 / 5 / 0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>126-300</td>
<td>16 / 18</td>
<td>4.8 / 3.5 / 0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>301-560</td>
<td>17 / 19</td>
<td>4.8 / 3.5 / 0.20</td>
<td>5 / 0.19 / 3.5 / 0.02 Tier 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>561+</td>
<td>19 / 21</td>
<td>5 / 0.19 / 3.5 / 0.04 Tier 2</td>
<td>0.67 / 0.40 / 3.5 / 0.10 Tier 2</td>
<td>0.67 / 0.19 / 3.5 / 0.09 Tier 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Technology Reference

- **Tier 3**: 0.40 / 0.19 / 3.5 / 0.02
- **Tier 2**: 0.67 / 0.40 / 3.5 / 0.10

---

### NG/LPG: Non-emergency

- **V** NG LB: 26-99
- **V** LPG LB: 26-99
- **M** LPG RB: >25

### NG/LPG: Emergency

- **V** NG & LB LPG: 26-129
- **M** LPG RB: 26-129

### Landfill / Digester Gas

- **V** All LB & RB: All

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**Cummins**

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## Engine Exhaust Pollutants

<table>
<thead>
<tr>
<th></th>
<th>Definition</th>
<th>Diesel Engine</th>
<th>Gaseous Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\text{\textsubscript{x}}</td>
<td>Oxides of nitrogen</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>HC</td>
<td>Over 100 different types of hydrocarbons</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PM</td>
<td>Anything that is trapped on or condenses onto a filter</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>Carbon Monoxide</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SO\text{\textsubscript{x}}</td>
<td>Oxides of Sulfur</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

PM and SO\text{\textsubscript{x}} are not regulated for Gaseous Engines
EPA NSPS for Spark Ignited Engine Summary

- Mandatory factory certification of rich burn propane engines
- Optional factory certification of all natural gas engines and lean burn propane engines
- If not factory certified, the owner/operator must perform certain tasks:

<table>
<thead>
<tr>
<th>Engine Power</th>
<th>Maintenance plan and records, maintain/operate engine in a way to minimize emissions</th>
<th>Initial performance testing within 1 year of engine startup</th>
<th>Subsequent performance testing every 8,760 hours or 3 years, whichever comes first</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100 hp</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-500 hp</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>&gt; 500 hp</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Reference: 40 CFR 60 Subpart JJJJ §60.4243 (a)(2)(i-iii)
What are some areas where Diesel and Gaseous generator sets have similar requirements?

a) ISO 8528 standard
b) NFPA 110 for Power Restoration
c) EPA regulations on exhaust emissions
d) All of the above
Concept Check

What are some areas where Diesel and Gaseous generator sets have similar requirements?

a) ISO 8528 standard
b) NFPA 110 for Power Restoration
c) EPA regulations on exhaust emissions
d) All of the above
Installation Similarities

- Exhaust systems – mounting, insulation, expansion
- Foundation & isolators – mass, size, securing
- Starting system – batteries and charger
- Noise considerations – location external or in room/housing
- Service & maintenance access – planned maintenance
- Monitoring systems – requirements and capabilities
- Housing requirements
Installation Differences

Maintenance of Diesel Fuel

- Fuel problems cause ~70% of diesel engine failures
  - Microbial growth in storage tanks contributes ~90%
  - Heavy-end asphaltene becomes unstable and drops out of fuel
- Ultra Low Sulfur Diesel (ULSD) – recommend additional testing and fuel treatment

https://www.government-fleet.com/157049/how-to-maintain-stored-diesel-fuel
Installation Differences

Maintenance of Gaseous Fuel

- Natural gas available through extensive pipeline network
- Avoid fuel transportation, handling, and storage issues
- No fuel tank cleaning required
- No fuel degradation over time
- Various fuels can be used
Gaseous Generators Sets Strengths

- Reliable power generation in emergency situations
  - No need to refuel where Natural Gas is available
  - Pipeline gas only used when needed
- Emissions solutions that fit your needs
  - Factory certification
  - Compliant capable
- High efficiency options
- Can cover all ISO8528 duty cycles
- Lower cost of ownership
- Transient performance comparable to Diesel
Natural Gas as a Fuel Source

- Natural Gas is
  - Reliable
  - Easy to maintain
  - Cost competitive

- In Florida, during Hurricane Charlie in 2004, Federal Emergency Management Agency (FEMA) reported that **50% of standby generators failed** ... traced to diesel fuel instability
Reliability of Natural Gas

NFPA 110-2016
5.1.1 The following energy sources shall be permitted to be used for the emergency power supply (EPS):

(3) Natural or synthetic gas

Exception: For Level 1 installations in locations where the probability of interruption of off-site fuel supplies is high, on-site storage of an alternate energy source sufficient to allow full output of the EPSS to be delivered for the class specified shall be required, with the provision for automatic transfer from the primary energy source to the alternate energy source.

Natural Gas Council
Natural gas is a secure, reliable and resilient choice for customers

- Operational reliability
  - 2017 survey of 51 interstate pipelines – 99.97% of contractual commitments
  - Geographic dispersion of production reduces vulnerability to local weather
  - Transportation network interconnected, offering multiple pathways for rerouting

- Contractual continuity of service
  - Firm or interruptible contracts
Fuel Cost

**Price of Natural Gas** - Cost effective and stable

- Natural gas generator set more expensive based on power density
- Comparable long-term costs based on maintenance & fuel (20 year)
- Demand Response requires T4F which driving costs, NG comparable (non-emergency)

www.eia.gov/naytrualgas
Common Misconceptions - Application

“Gaseous generator sets do not work in Standby applications”

✓ Most rich burn generator sets are compliant to NPFA 110 Type 10

✓ Lean burn generator sets can operate in Standby non Emergency applications

![Diagram showing the application of different types of generator sets](image-url)
Common Misconception- Emissions

“All Gaseous generator sets can operate without aftertreatment”

✓ Some rich burn generator sets will need to have aftertreatment
✓ Most lean burn generator sets can operate without aftertreatment
Common Misconception- Transient Performance

“All Gaseous generator sets have poor Transient Performance”

✓ Full load acceptance is not a true indicator of engine performance
✓ Engine control technology is changing
✓ Use engine manufacturer’s sizing tool to ensure adequate performance

<table>
<thead>
<tr>
<th></th>
<th>250KW</th>
<th></th>
<th>750KW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diesel</td>
<td>RB Gas</td>
<td>Diesel</td>
<td>RB Gas</td>
</tr>
<tr>
<td><strong>Full Load Acceptance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Dip</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Dip</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Full Load Rejection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Concept Check

When both natural gas and diesel fuel are available for a project, it is best to specify which criteria for optimal generator set selection

a) Transient Voltage/Frequency deviation and recovery time
b) Exhaust Emissions (EPA and local as applicable)
c) Generator Set Rating
d) All of the above
When both natural gas and diesel fuel are available for a project, it is best to specify which criteria for optimal generator set selection:

a) Transient Voltage/Frequency deviation and recovery time
b) Exhaust Emissions (EPA and local as applicable)
c) Generator Set Rating
d) All of the above
### Selection Considerations

<table>
<thead>
<tr>
<th>Standby</th>
<th>Diesel</th>
<th>Rich Burn</th>
<th>Lean Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient Performance</td>
<td>+</td>
<td>+</td>
<td>+/-</td>
</tr>
<tr>
<td>Reliability of Fuel Supply</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Exhaust Emissions</td>
<td>-</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

**Typical Fuel Cost Ratio:**  
~ 6 : 1 (Diesel : NG) @ 1MW-hr
Installation Considerations - Fuel Supply

- Volume and pressure must be available at **RATED** load, not static pressure
- Pressure drop
- Accumulator or compressor to boost pressure, if necessary
- Refer to the datasheet for specifics

### Fuel system

<table>
<thead>
<tr>
<th>Gas supply pressure to engine inlet, bar (psi)</th>
<th>0.2 (2.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum methane index</td>
<td>62</td>
</tr>
</tbody>
</table>

**Spec Note** Check the site fuel pressure and ensure that it meets the generator set fuel supply pressure requirement
Installation Considerations - Fuel Regulation

- Final stage provided on the engine
- Additional regulator(s) required if ‘high’ pressure supply
  
  **Example** 30 PSI supply to 0.5 PSI engine inlet in one step will limit engine responsiveness
Installation Considerations - Cooling

- Heat produced by NG generator is typically higher
- 40°C (104°F) or 50°C (122°F) ambient rating
  - Radiator core restriction causes additional cooling reduction

**COOLING SYSTEM: 40 °C AMBIENT 0.50 H2O RESTRICTION**

The cooling system was tested at full rated load in accordance with Cummins Initial Quality Audit standards. Performance was empirically determined to meet the listed rating.

**Spec Note** Require generator set manufacturer to provide the cooling package options and recommendation
### Installation Considerations – Sound

- Gaseous and diesel fueled generator sets sound different, but sound power levels may be similar
  - Fan noise may be higher for Natural Gas
- Sound attenuated enclosures available for both diesel and gaseous generator sets

<table>
<thead>
<tr>
<th>Full Load Acceptance</th>
<th>Position (Note 1)</th>
<th>8-pos Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>T2 Diesel</td>
<td>89.5</td>
<td>91.6</td>
</tr>
<tr>
<td>RB NG</td>
<td>84.6</td>
<td>90.8</td>
</tr>
</tbody>
</table>

Note 1. Position 1 faces the Generator Set (GenSet) front per ISO 8528-10. The positions proceed around the GenSet in a counterclockwise direction in 45° increments. All positions are at 7 m (23 ft) from the surface of the GenSet and 1.2 m (48 in) from floor level.
Concept Check

Some of the key installation considerations of gaseous generator sets include

a) Fuel supply and regulation
b) Cooling
c) Sound
d) All of the above
Concept Check

Some of the key installation considerations of gaseous generator sets include

a) Fuel supply and regulation
b) Cooling
c) Sound
d) All of the above
Course Summary

Specifying Gaseous Generator Sets

• Recognize the similarities and distinctions between gaseous and diesel generator sets
• Describe key features and capabilities of gaseous generator sets
• List some key considerations for gaseous generator sets installation

Key Takeaways

• Write your specifications based on performance and application needs such loads, emissions etc. and not on the fuel type
• Consider gaseous powered generators in your specification, even in life-safety applications
Q&A

Type your questions, comments, feedback in the WebEx Q&A box. We will get to as many questions as we can.

We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

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Closing

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