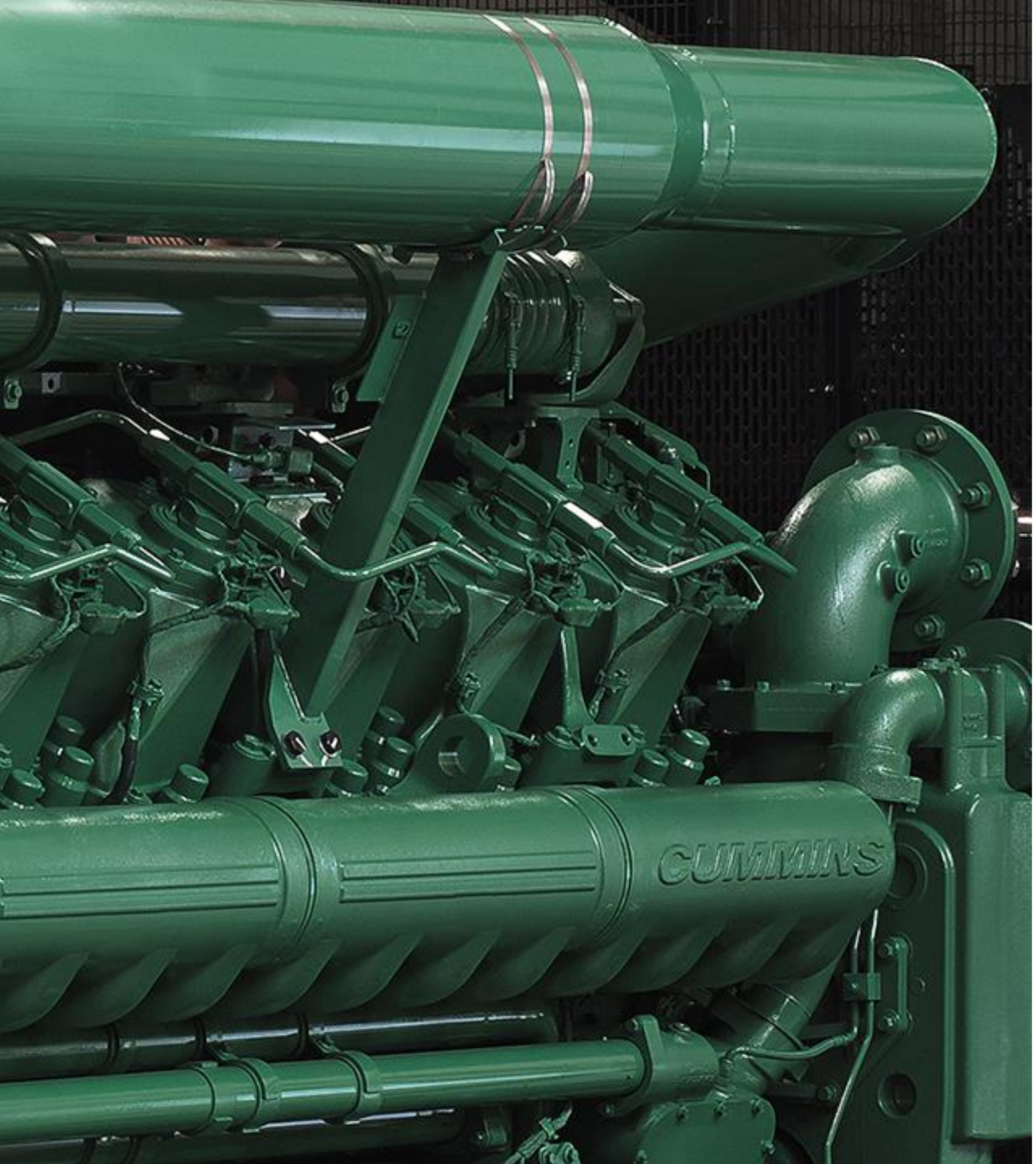

Considerations for Specifying Generator Set Fuel Sources

PowerHour webinar series for consulting engineers

Experts you trust. Excellence you count on.

January 28, 2020 11:00 PDT / 13:00 CDT

(1PDH issued by Cummins)

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- Earn Professional Development Hours (PDH)

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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 it doubt, reach out to the Authority Having Jurisdiction.

Course Objectives

Considerations for Specifying Generator Set Fuel Sources

The installation of gaseous generator sets in a wide variety of applications continues to rise in North America while facility performance requirements, codes and standards are often most closely linked to their traditional diesel counterpart. As natural gas and propane fueled generator sets reach the market with “diesel-like” performance, it’s critical to understand how best to apply these products in order to maximize the value they provide. This course will provide an overview of gaseous generator set capabilities in various applications and will empower participants to recognize how to best apply gaseous generator sets to meet common performance and code requirements.

After completing this course, participants will be able to:

- Recognize performance requirements applicable to both diesel and gaseous generator sets.
- Describe key features and capabilities of gaseous generator sets.
- List key considerations unique to gaseous generator set installation.

When compared to a diesel generator set, what are some of the differentiators unique to a natural gas (or propane) fueled generator set?

Generator Set Fuel Sources

Diesel and Gaseous Fuels

Diesel Fuel

- Power dense, high energy content
- ULSD Diesel #2 ASTM D975

Generator Set Fuel Sources

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- Variable energy content
- “Pipeline natural gas”

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Gaseous Fuel

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Diesel Fuel
Gasoline
Propane Liquid Gas
Propane gas
Natural Gas

Relative Energy Density

Generator Set Fuel Sources

Gaseous Fuels

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

Generator Set Fuel Sources

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Spec Note Conduct a fuel sample analysis, include the results in the specification and require manufacturers to provide documentation demonstrating capability with the on-site fuel.

Generator Set Fuel Sources

Gaseous Fuels - Methane Number

Methane Index Number (MN)

- Defines likelihood of a fuel to auto-ignite
- Scale of 0-100

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  - Lower MN may be more likely to auto-ignite (knock) and may require power derate and/or timing changes.

Methane number capability

Load (percent of rated)			
100%	90%	75%	50%
72	66	57	42

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- High quality pipeline natural gas is typically 80-90 MN.

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100%	90%	75%	50%
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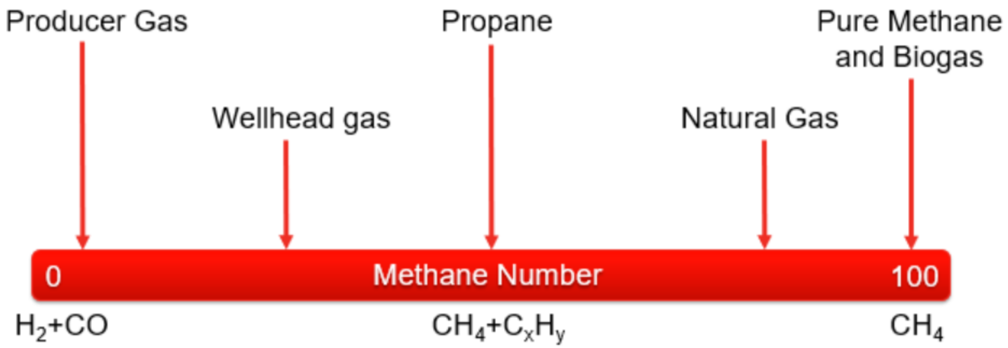

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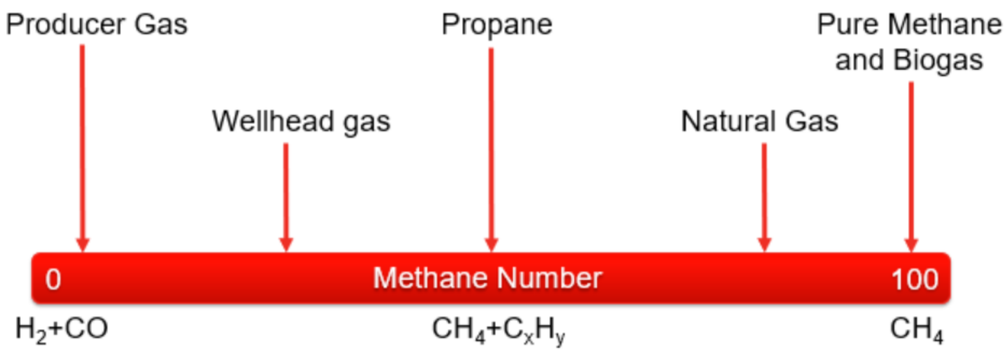

Spec Note Require generator set manufacturers to provide documentation indicating product performance at a specified Methane Number or range based on site fuel sample analysis.

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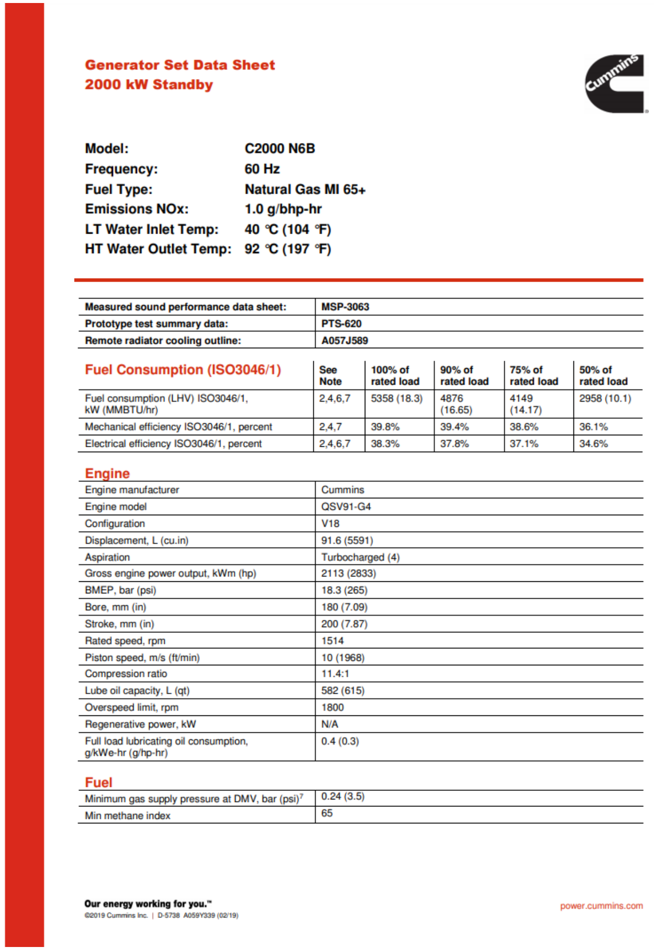

Generator Set Data Sheet
2000 kW Standby

Model:	**C2000 N6B**
Frequency:	**60 Hz**
Fuel Type:	**Natural Gas MI 65+**
Emissions NOx:	**1.0 g/bhp-hr**
LT Water Inlet Temp:	**40 °C (104 °F)**
HT Water Outlet Temp:	**92 °C (197 °F)**

Measured sound performance data sheet:	**MSP-3063**
Prototype test summary data:	**PTS-620**
Remote radiator cooling outline:	**A057J589**

Fuel Consumption (ISO3046/1)	See Note	100% of rated load	90% of rated load	75% of rated load	50% of rated load
Fuel consumption (LHV) ISO3046/1, kW (MMBTU/hr)	2,4,6,7	5358 (18.3)	4876 (16.65)	4149 (14.17)	2958 (10.1)
Mechanical efficiency ISO3046/1, percent	2,4,7	39.8%	39.4%	38.6%	36.1%
Electrical efficiency ISO3046/1, percent	2,4,6,7	38.3%	37.8%	37.1%	34.6%

Engine

Engine manufacturer	Cummins
Engine model	QSV91-G4
Configuration	V18
Displacement, L (cu.in)	91.6 (5591)
Aspiration	Turbocharged (4)
Gross engine power output, kWm (hp)	2113 (2833)
BMEP, bar (psi)	18.3 (265)
Bore, mm (in)	180 (7.09)
Stroke, mm (in)	200 (7.87)
Rated speed, rpm	1514
Piston speed, m/s (ft/min)	10 (1968)
Compression ratio	11.4:1
Lube oil capacity, L (qt)	582 (615)
Overspeed limit, rpm	1800
Regenerative power, kW	N/A
Full load lubricating oil consumption, g/kWe-hr (g/hp-hr)	0.4 (0.3)

Fuel

Minimum gas supply pressure at DMV, bar (psi)[7]	0.24 (3.5)
Min methane index	65

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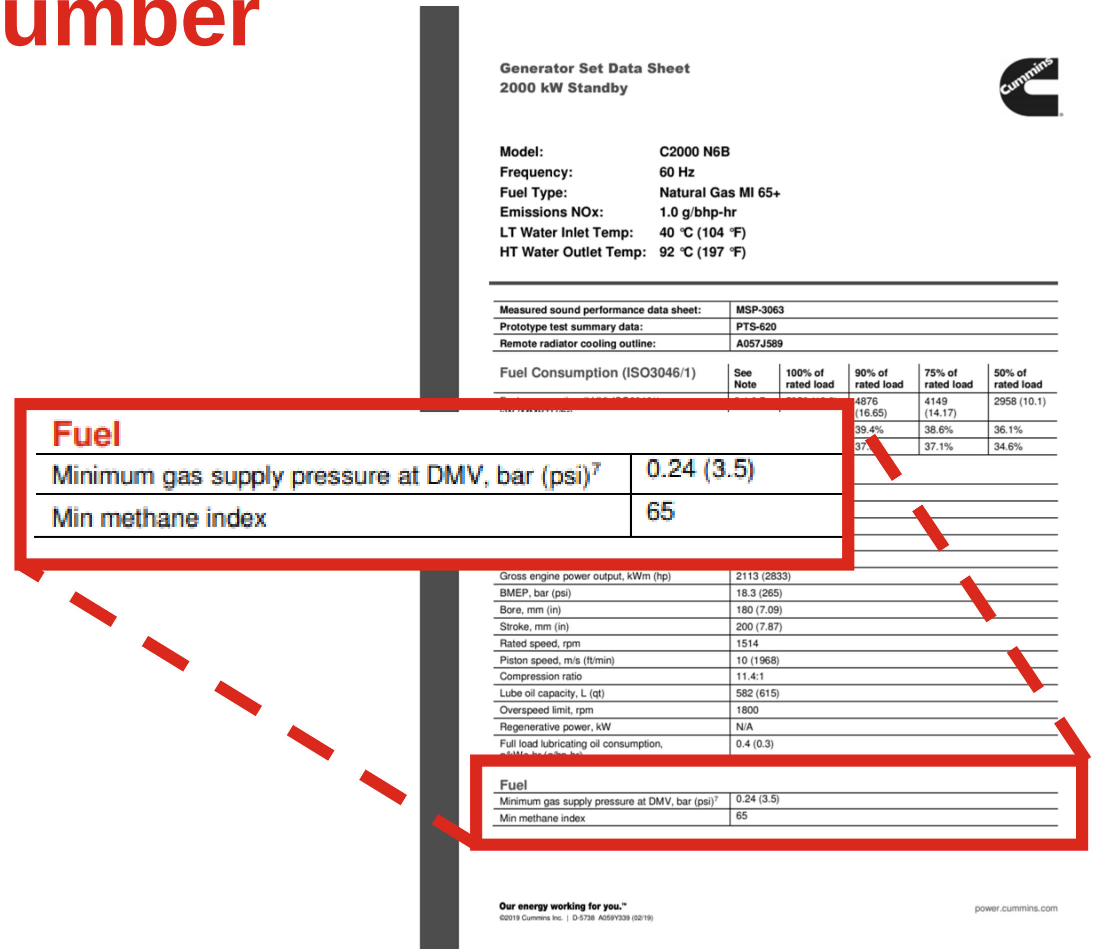

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Generator Set Fuel Sources

Rich Burn and Lean Burn Engines

	Rich Burn	Lean Burn

Generator Set Fuel Sources

Rich Burn and Lean Burn Engines

	Rich Burn	Lean Burn
Air Fuel Ratio		
Excess Air (O_2)		
Typical Application		
Emissions		

Generator Set Fuel Sources

Rich Burn and Lean Burn Engines

	Rich Burn	Lean Burn
Air Fuel Ratio	~14.6 : 1	
Excess Air (O_2)	0.2 to 0.8%	
Typical Application	Fast start, large block loads	
Emissions	Aftertreatment may be required to reduce NOx and CO	

Generator Set Fuel Sources

Rich Burn and Lean Burn Engines

	Rich Burn	Lean Burn
Air Fuel Ratio	~14.6 : 1	~25 : 1
Excess Air (O_2)	0.2 to 0.8%	>4%
Typical Application	Fast start, large block loads	High efficiency, continuous operation, ramping load
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Spec Note Specify project requirements critical to the generator set such as transient performance, motor starting capability or emissions limits. Avoid specifying “Rich Burn” or “Lean Burn” as it may drive unnecessary product requirements.

Concept Check

When describing gaseous fuels, which of the following attributes are often used to describe fuel composition? Choose all that apply.

a) Methane Number (MN)

b) Energy Density (BTU/ft^3 or MMBTU)

c) ASTM D975

d) Air/Fuel Ratio

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Compliance to Codes and Standards

Fuel Source for Emergency Systems

NFPA 110-2019

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

(1) Liquid petroleum products…

(2) Liquified petroleum gas…

(3) Natural or synthetic gas

Compliance to Codes and Standards

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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.

Compliance to Codes and Standards

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Natural Gas Council

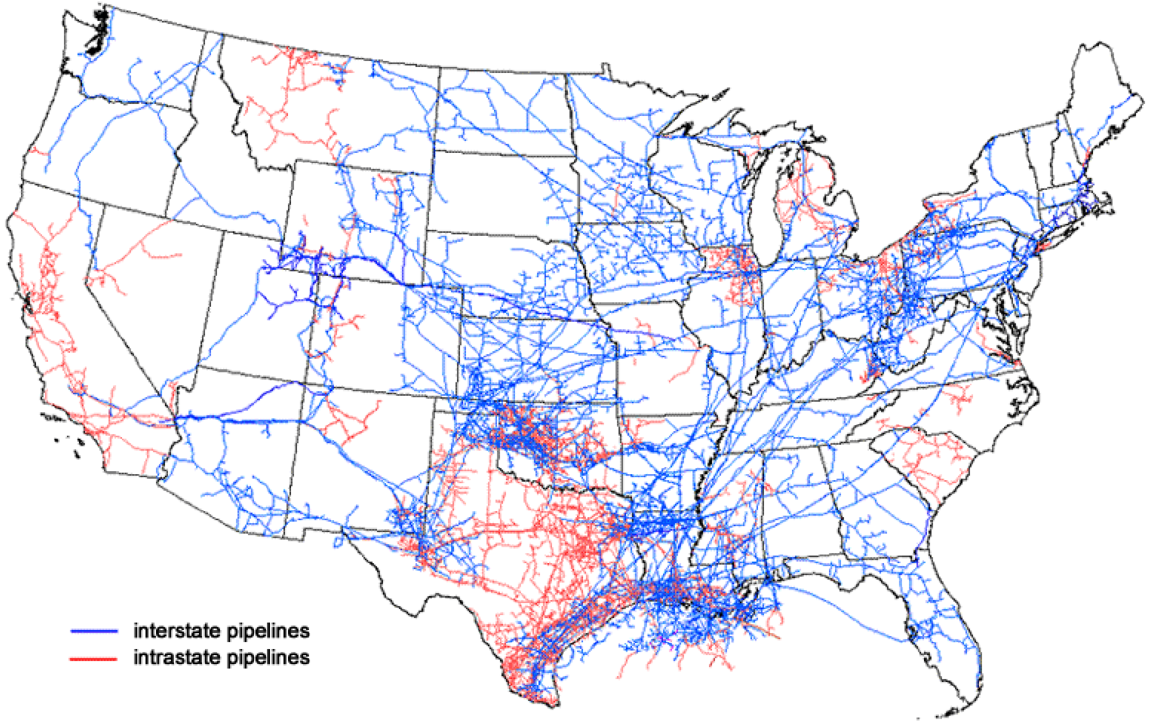
Natural gas is a secure, reliable and resilient choice for customers

- 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

Compliance to Codes and Standards

Fuel Source for Emergency Systems

Map of U.S. interstate and intrastate natural gas pipelines



Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

Compliance to Codes and Standards

Fuel Source for Emergency Systems

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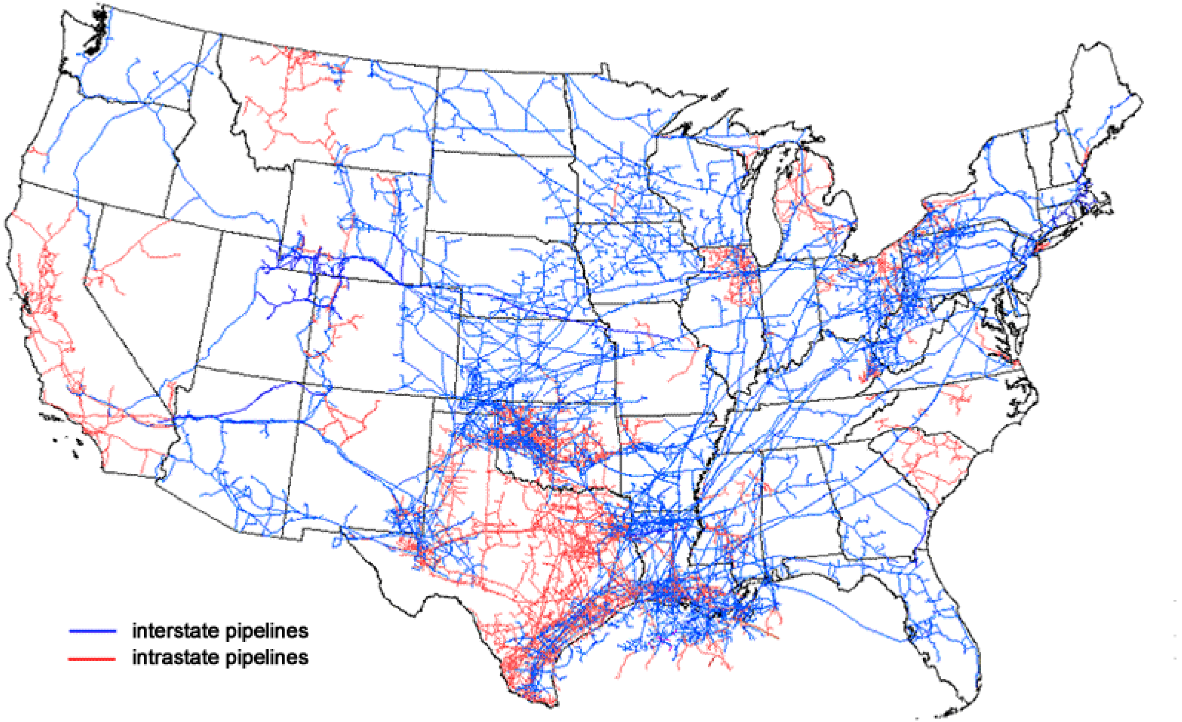

Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

Spec Note Specify natural-gas fueled generator sets for emergency power systems where permitted by the local Authority Having Jurisdiction.

Compliance to Codes and Standards

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.

International Organization for Standardization.2018-02.ISO 8528-1.www.iso.org

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ISO 8528 is a reference standard that only describes duty cycle, NOT fuel type.

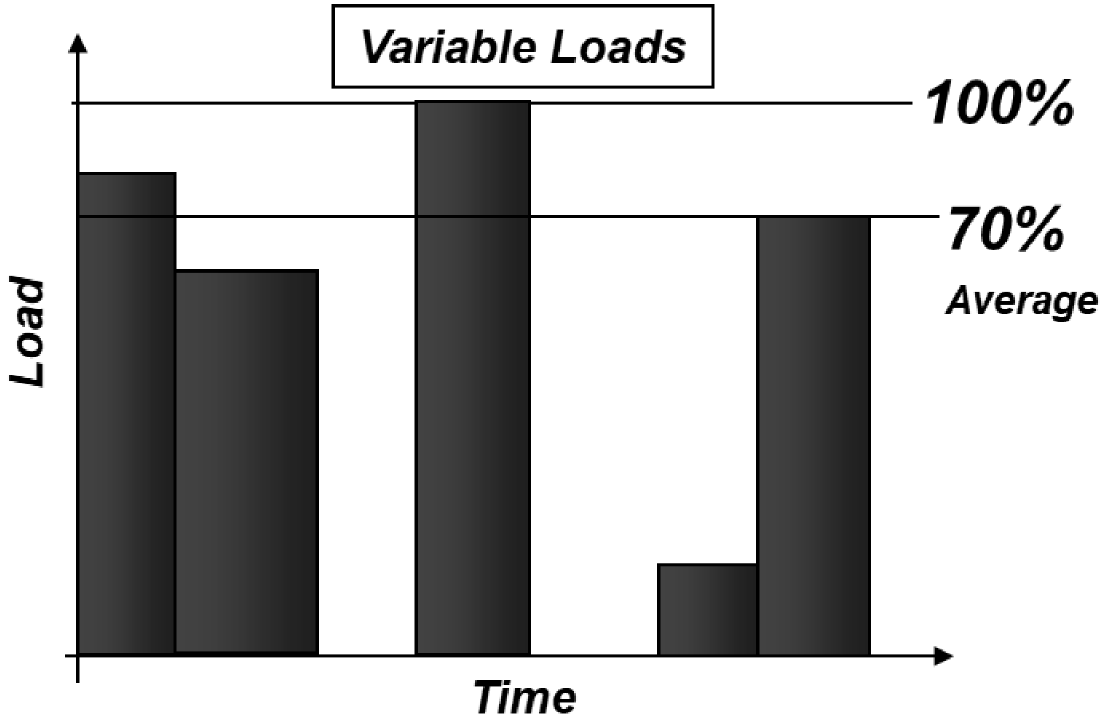
Spec Note Include ISO 8528 in specification codes and standards reference.

Compliance to Codes and Standards

Generator Set Ratings

Emergency Standby Power (ESP)

- “Maximum power available during a variable electrical power sequence…for up to 200 h of operation per year”
- “The permissible average power output over 24 h of operation shall not exceed 70% of the ESP unless otherwise agreed by the RIC engine manufacturer”



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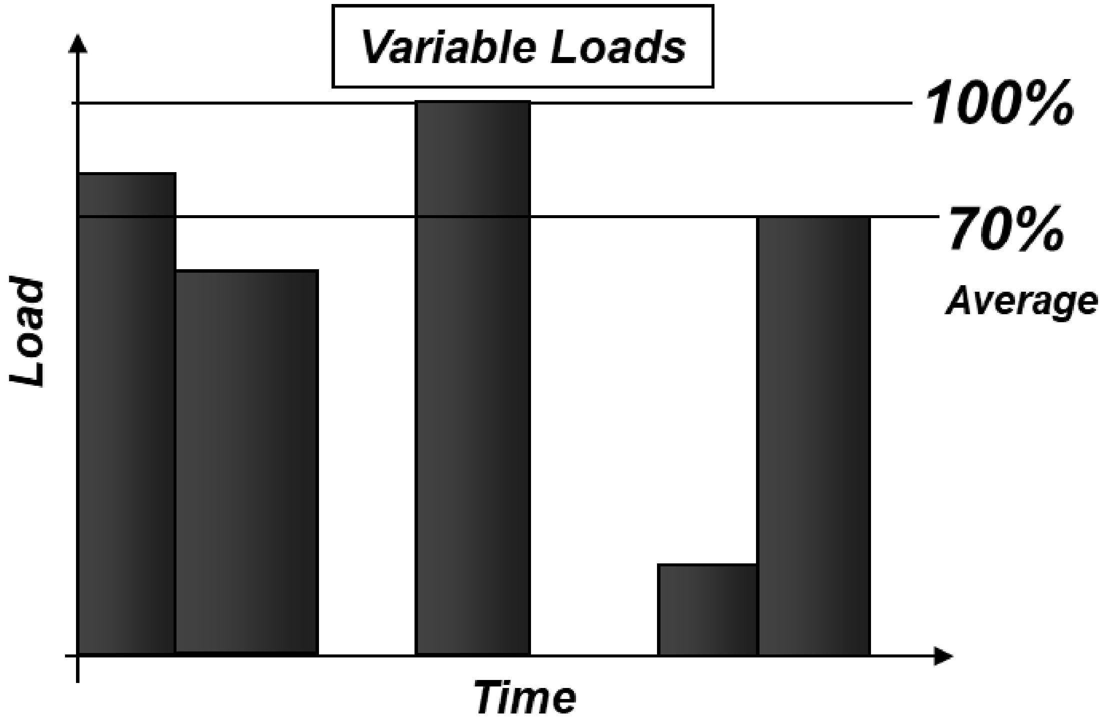

Spec Note Specify ISO 8528 generator set power rating based on application requirements.

Compliance to Codes and Standards

NFPA 110 Type Requirements

4.3 Type. The type defines the maximum time, in seconds, that the EPSS will permit the load terminals of the transfer switch to be without acceptable electrical power.

Compliance to Codes and Standards

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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

Compliance to Codes and Standards

NFPA 110 Type Requirements

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Spec Note Specify NFPA 110 Type requirement for Emergency Power Supply System based on application requirements and loads served.

Compliance to Codes and Standards

Emissions Requirements

US EPA New Source Performance Standards (NSPS)

Compliance to Codes and Standards

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US EPA New Source Performance Standards (NSPS)

Fuel Type

- Compression Ignition (Diesel) and Spark-Ignited (Gaseous)

Compliance to Codes and Standards

Emissions Requirements

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Usage

- Stationary Emergency – operation when utility power is not available
- Stationary Non-Emergency – operation when utility power is available
- Non-road – mobile, non-propulsion without operational limitation (trailerized)

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Spec Note Require generator set vendors to provide documentation demonstrating compliance with applicable limits of U.S. EPA New Source Performance Standards for stationary emergency or non-emergency engines as appropriate.

Compliance to Codes and Standards

Emissions Requirements

	Definition	Diesel Engine	Gaseous Engine
NO_x	Oxides of nitrogen	✓	✓
HC	Over 100 different types of hydrocarbons	✓	✓
PM	Anything that is trapped on or condenses onto a filter	✓	
CO	Carbon Monoxide	✓	✓
SO_x	Oxides of Sulfur	✓	

Compliance to Codes and Standards

Emissions Requirements

- 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 may be responsible for demonstrating compliance:

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

Reference: 40 CFR 60 Subpart JJJJ §60.4243 (a)(2)(i-iii)

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> 500 hp	✓	✓	✓

Reference: 40 CFR 60 Subpart JJJJ §60.4243 (a)(2)(i-iii)

Spec Note Require generator set vendor to provide documentation demonstrating compliance with specific emissions levels or engine certification.

Compliance to Codes and Standards

Emissions Requirements

US EPA New Source Performance Standards (NSPS)

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Local Air Quality Management Board

- May mandate stringent emissions limits requiring exhaust aftertreatment

Compliance to Codes and Standards

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Local Air Quality Management Board

- May mandate stringent emissions limits requiring exhaust aftertreatment

Spec Note Require generator set vendor to provide documentation demonstrating compliance with specific emissions level requirement and applicable test methodology.

Concept Check

When specifying a generator set solution for an emergency power system, make sure to include… (choose all that apply)

a) US EPA and other applicable emissions requirements

b) ISO 8528 Power rating

c) Fuel type

d) NFPA 110 Type requirement for system

e) Engine air/fuel ratio

Concept Check

When specifying a generator set solution for an emergency power system, make sure to include… (choose all that apply)

a) US EPA and other applicable emissions requirements

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Installation Considerations

Gaseous and Diesel Generator Sets

- Foundation, mounting and vibration isolation
- Exhaust systems
- Cooling and ventilation
- Starting system
- Sound considerations
- Service and maintenance access
- Remote monitoring solutions
- Housing and enclosure requirements

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Consult Cummins Application Engineering T-030: Liquid-Cooled Generator Set Application Manual for more information.

Installation Considerations

Fuel Source and Maintenance

Maintenance of Diesel Fuel

Diesel fuel quality critical to equipment operation.

- Typical stable lifespan of diesel is 12 – 16 months in ideal conditions.
- Diesel sulfur content reduction (ULSD) limits fuel’s anti-microbial properties.
- Bio-diesel blending may reduce fuel stability (up to 6 months), promotes water absorption and biomass growth.

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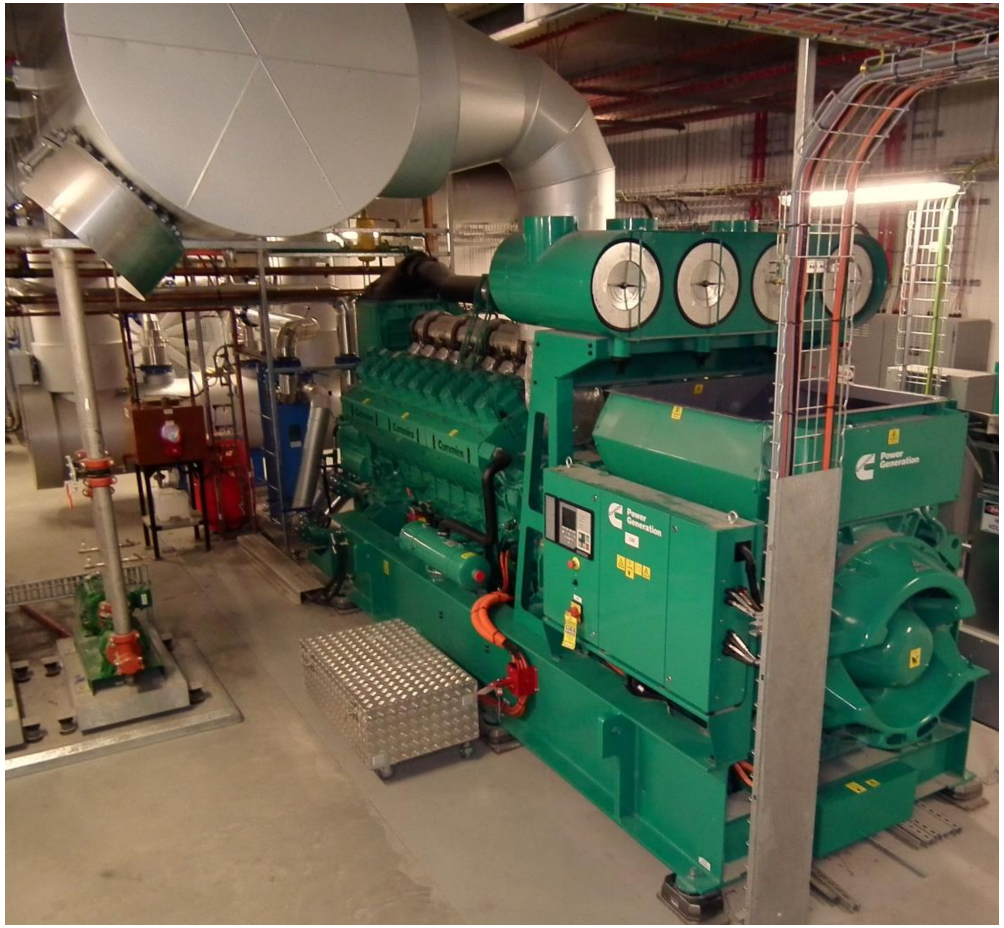
Spec Note Require vendors to provide service and maintenance contracts that include fuel testing at least annually.

Installation Considerations

Fuel Source and Maintenance

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



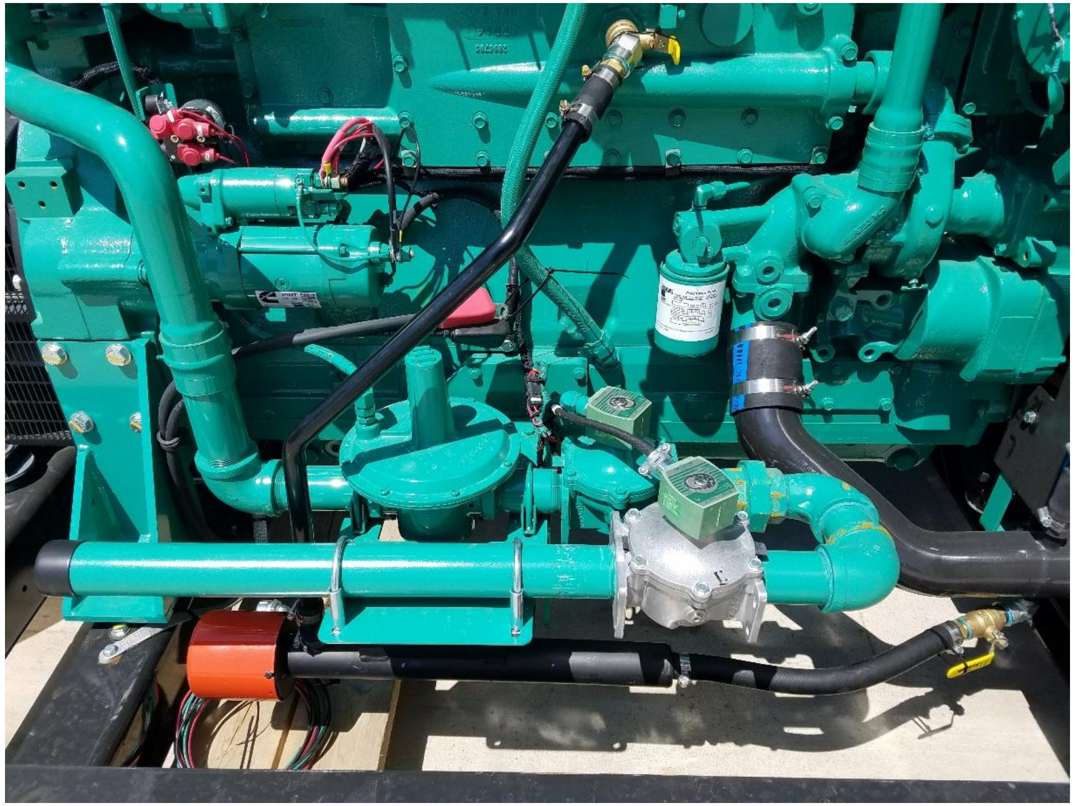
Installation Considerations

Fuel System Requirements

- Volume and pressure must be available at **RATED** load, not static pressure
- Be aware of fuel system pressure drop
- Accumulator or compressor to boost pressure, if necessary
- Consult generator set manufacturer for specific fuel system requirements.

Fuel system

Gas supply pressure to engine inlet, bar (psi)[8]	0.2 (2.9)
Minimum methane index	62



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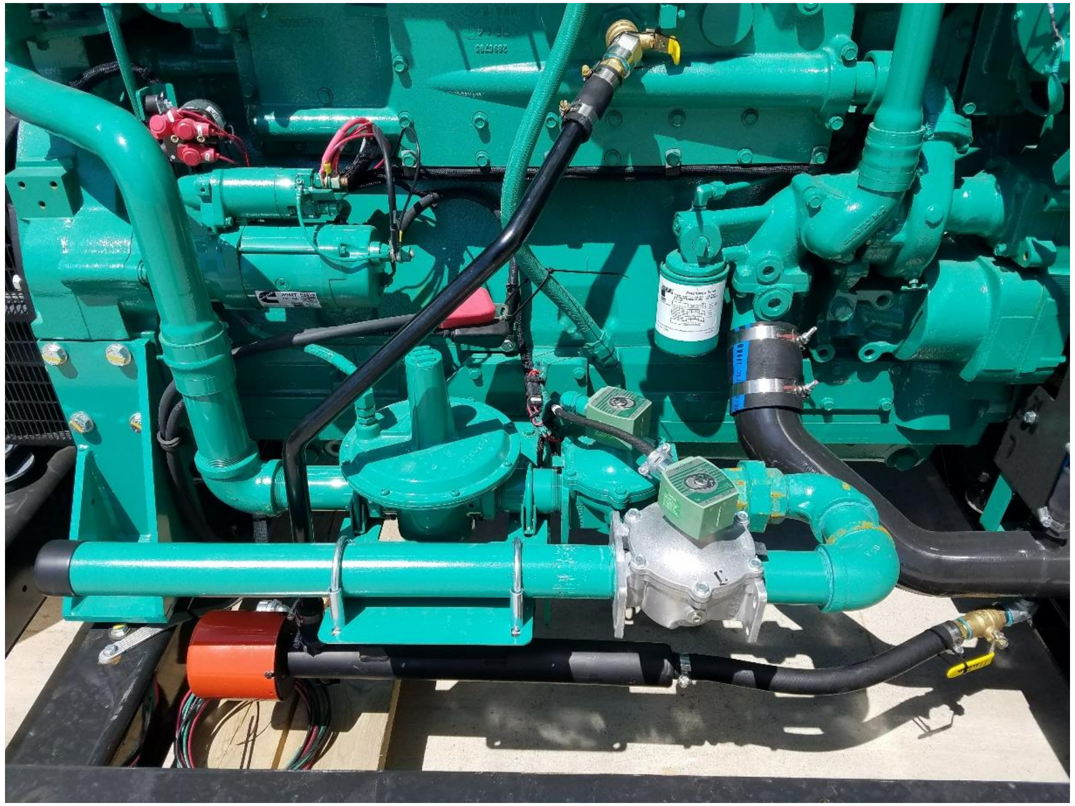

Fuel system

Gas supply pressure to engine inlet, bar (psi)[8]	0.2 (2.9)
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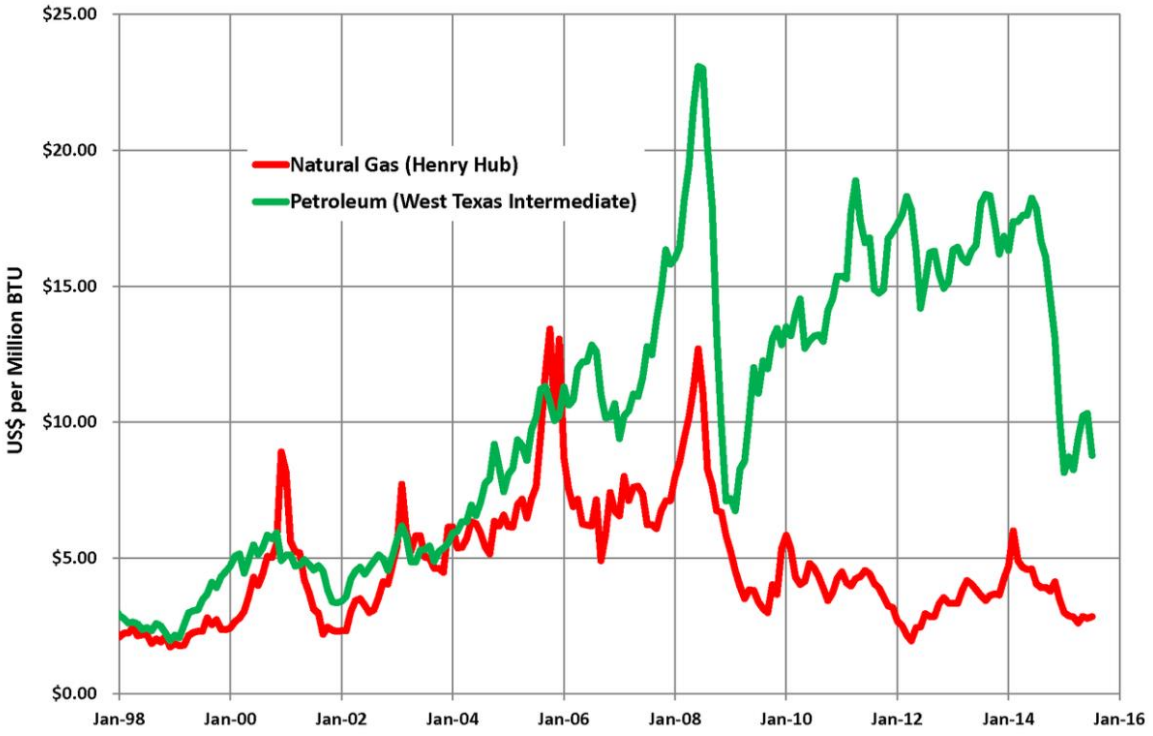
Spec Note Require generator set vendors to provide documentation indicating engine minimum fuel pressure at rated load.

Operational Considerations

Operating Costs of NG-Fueled Generator Sets

Natural Gas Operating Costs

- Natural gas generator set may be associated with greater capital costs (when compared to diesel) due to power density.
- Long term total cost of ownership indicates for diesel and natural gas products to be comparable in similar applications.
- Non-emergency operation (demand response, peaking, etc.) mandates Tier 4 levels for CI engines minimizing capital investment difference when compared to natural gas.



www.eia.gov/naturalgas

Concept Check

When considering natural gas generator sets, what are some of the key installation and operational differentiators when compared to diesel generator sets? (choose all that apply)

a) Sound attenuation and mufflers

b) Fuel system design requirements

c) Fuel quality management

d) Foundation, mounting and vibration

e) Cost of operation

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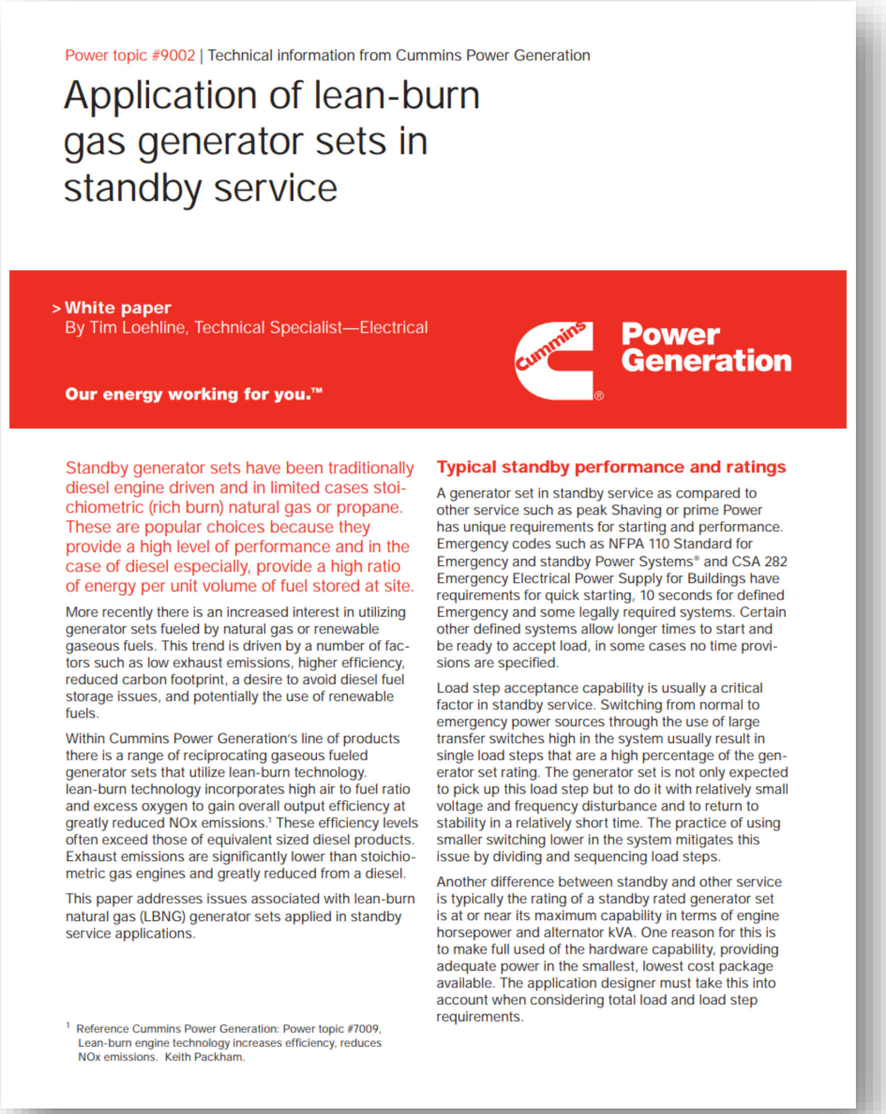
Gaseous Generator Set Applications

Myths and Misconceptions

MYTH: "Gaseous generator sets may not be suitable for emergency or life safety applications."

- ✓ Generator set manufacturers may be able to offer gaseous-fueled products that meet a wide range of applications.
- ✓ Natural gas may be acceptable to local authority having jurisdiction for life safety applications.
- ✓ Gaseous products may provide advantages over diesel products in applications due to fuel quality and logistics.



Power topic #9002 | Technical information from Cummins Power Generation

Application of lean-burn gas generator sets in standby service

> White paper
By Tim Loehline, Technical Specialist—Electrical

Our energy working for you.™

Power Generation

Standby generator sets have been traditionally diesel engine driven and in limited cases stoichiometric (rich burn) natural gas or propane. These are popular choices because they provide a high level of performance and in the case of diesel especially, provide a high ratio of energy per unit volume of fuel stored at site.

More recently there is an increased interest in utilizing generator sets fueled by natural gas or renewable gaseous fuels. This trend is driven by a number of factors such as low exhaust emissions, higher efficiency, reduced carbon footprint, a desire to avoid diesel fuel storage issues, and potentially the use of renewable fuels.

Within Cummins Power Generation's line of products there is a range of reciprocating gaseous fueled generator sets that utilize lean-burn technology. lean-burn technology incorporates high air to fuel ratio and excess oxygen to gain overall output efficiency at greatly reduced NOx emissions.[1] These efficiency levels often exceed those of equivalent sized diesel products. Exhaust emissions are significantly lower than stoichiometric gas engines and greatly reduced from a diesel.

This paper addresses issues associated with lean-burn natural gas (LBNG) generator sets applied in standby service applications.

Typical standby performance and ratings

A generator set in standby service as compared to other service such as peak Shaving or prime Power has unique requirements for starting and performance. Emergency codes such as NFPA 110 Standard for Emergency and standby Power Systems® and CSA 282 Emergency Electrical Power Supply for Buildings have requirements for quick starting, 10 seconds for defined Emergency and some legally required systems. Certain other defined systems allow longer times to start and be ready to accept load, in some cases no time provisions are specified.

Load step acceptance capability is usually a critical factor in standby service. Switching from normal to emergency power sources through the use of large transfer switches high in the system usually result in single load steps that are a high percentage of the generator set rating. The generator set is not only expected to pick up this load step but to do it with relatively small voltage and frequency disturbance and to return to stability in a relatively short time. The practice of using smaller switching lower in the system mitigates this issue by dividing and sequencing load steps.

Another difference between standby and other service is typically the rating of a standby rated generator set is at or near its maximum capability in terms of engine horsepower and alternator kVA. One reason for this is to make full used of the hardware capability, providing adequate power in the smallest, lowest cost package available. The application designer must take this into account when considering total load and load step requirements.

[1] Reference Cummins Power Generation: Power topic #7009, Lean-burn engine technology increases efficiency, reduces NOx emissions. Keith Packham.

Gaseous Generator Set Applications

Myths and Misconceptions

MYTH: "Because gaseous generator sets are cleaner than their diesel counterparts, they NEVER need exhaust aftertreatment."

- ✓ Emissions limits may be based on a combination of Federal (US EPA), state (local air board) or customer-driven requirements.
- ✓ Application type (standby vs. nonroad, emergency vs. non-emergency) drive emissions limits.
- ✓ Engine manufacturers offer a wide range of products capable of meeting the most stringent requirements.
- ✓ In some cases, exhaust aftertreatment may be needed to achieve targeted emissions levels.

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Spec Note Require generator set vendor to provide documentation demonstrating compliance with specific emissions level requirement and applicable test methodology.

Gaseous Generator Set Applications

Myths and Misconceptions

MYTH: "Gaseous generator set transient performance and load acceptance is always worse than their diesel counterparts."

- ✓ Rated load acceptance may not be suitable as a benchmark for product performance – transient performance limits must be based on application.
- ✓ Generator set sizing software may help to determine right-size generator set for a given application.
- ✓ Engine control and fueling strategies continue to evolve.

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	250KW		750KW	
	Diesel	RB Gas	Diesel	RB Gas
Full Load Acceptance				
Voltage Dip				
Recovery Time				
Frequency Dip				
Recovery Time				
Full Load Rejection				
Voltage Rise				
Recovery Time				
Frequency Rise				
Recovery Time				

60 Hz, 0.8 Power Factor

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60 Hz, 0.8 Power Factor

Spec Note Require generator set vendors to provide documentation from sizing software indicating compliance with transient and other project limits.

Gaseous Generator Sets

Key Takeaways

Natural gas fueled generator sets can provide…

… reliable power generation in emergency and non-emergency applications

… emissions solutions that fit application requirements

… high efficiency options for prime and continuous operation

… compliance with appropriate codes and standards

… low or comparable cost of ownership

… strong performance capability comparable to diesel counterparts.

Course Summary

Considerations for Specifying Generator Set Fuel Sources

- Recognize performance requirements applicable to both diesel and gaseous generator sets.
- Describe key features and capabilities of gaseous generator sets.
- List key considerations unique to gaseous generator set installation.

Key Takeaways

- Write specifications based on performance and application requirements such loads, transient limits, emissions, start-time and other code-driven requirements.
- Consider gaseous-fueled generator sets in applications where appropriate.

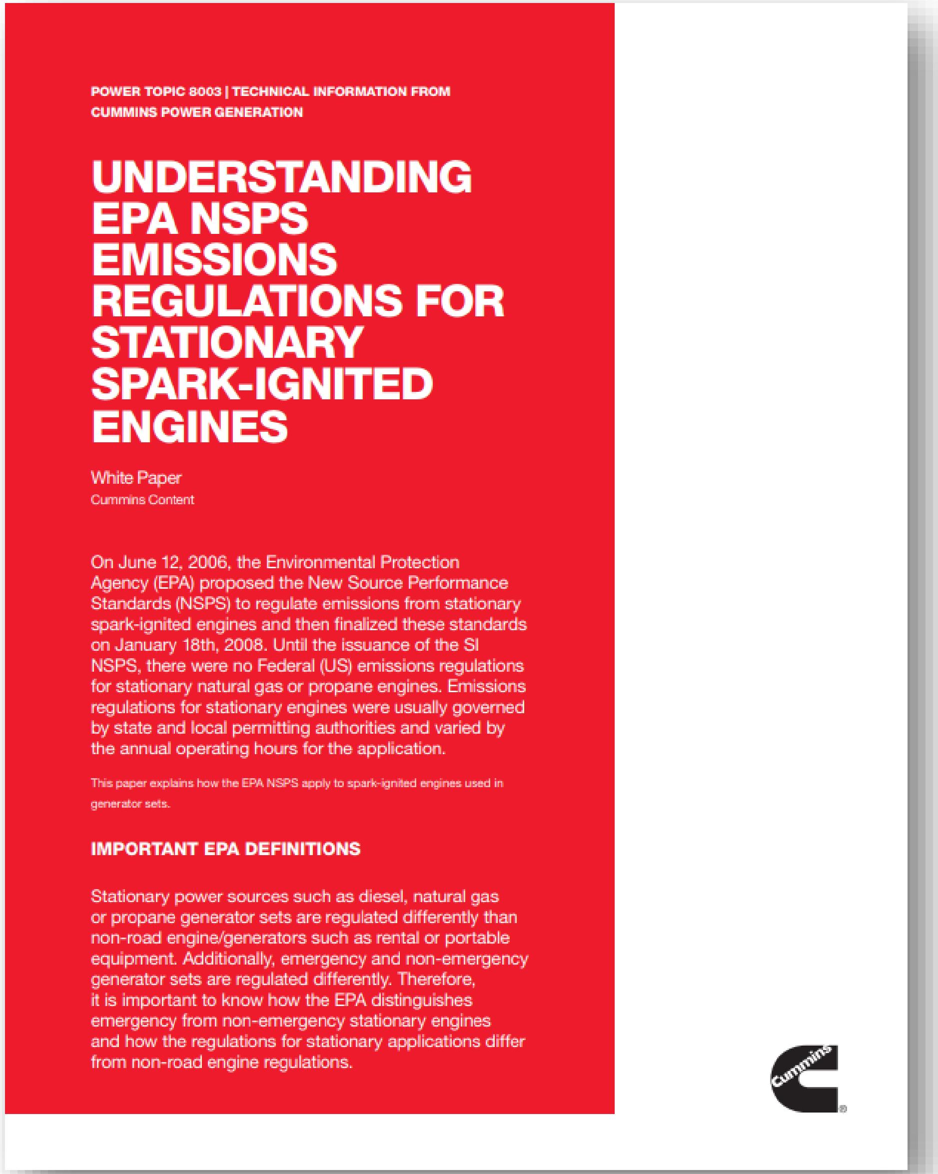
Additional Resources

Cummins White Papers

- Understanding EPA NSPS Emissions Regulations for Stationary Spark-ignited Engines
- The Latest Evolution Of Distributed Energy Resources: Opportunity For Business Within The PJM
- Utilizing Flare Gas To Generate Power For The Oil And Gas Sector
- Palm Oil Mill Effluent in Lean Burn Natural Gas Generator Sets

Cummins On-Demand Webinars

- Lean Burn Natural Gas Generator Sets in Standby-Peak Shaving Applications
- Specifying Gaseous Generator Sets
- Introduction to Generator Set Sizing Software
- EPA Emissions and Air Permitting



POWER TOPIC 8003 | TECHNICAL INFORMATION FROM CUMMINS POWER GENERATION

UNDERSTANDING EPA NSPS EMISSIONS REGULATIONS FOR STATIONARY SPARK-IGNITED ENGINES

White Paper
Cummins Content

On June 12, 2006, the Environmental Protection Agency (EPA) proposed the New Source Performance Standards (NSPS) to regulate emissions from stationary spark-ignited engines and then finalized these standards on January 18th, 2008. Until the issuance of the SI NSPS, there were no Federal (US) emissions regulations for stationary natural gas or propane engines. Emissions regulations for stationary engines were usually governed by state and local permitting authorities and varied by the annual operating hours for the application.

This paper explains how the EPA NSPS apply to spark-ignited engines used in generator sets.

IMPORTANT EPA DEFINITIONS

Stationary power sources such as diesel, natural gas or propane generator sets are regulated differently than non-road engine/generators such as rental or portable equipment. Additionally, emergency and non-emergency generator sets are regulated differently. Therefore, it is important to know how the EPA distinguishes emergency from non-emergency stationary engines and how the regulations for stationary applications differ from non-road engine regulations.

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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- A Link to webinar recording and presentation
- A PDH Certificate

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- Other Cummins Continuing Education programs
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Upcoming PowerHour Webinars:

- February – Understanding and Applying UL 1008 Transfer Switch Withstand and Closing Rating
- March – Advanced Generator Sizing: Transient Performance and Motor Loads

Please contact Mohammed Gulam if you have any questions related to the PowerHour webinar (mohammed.gulam@cummins.com)


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