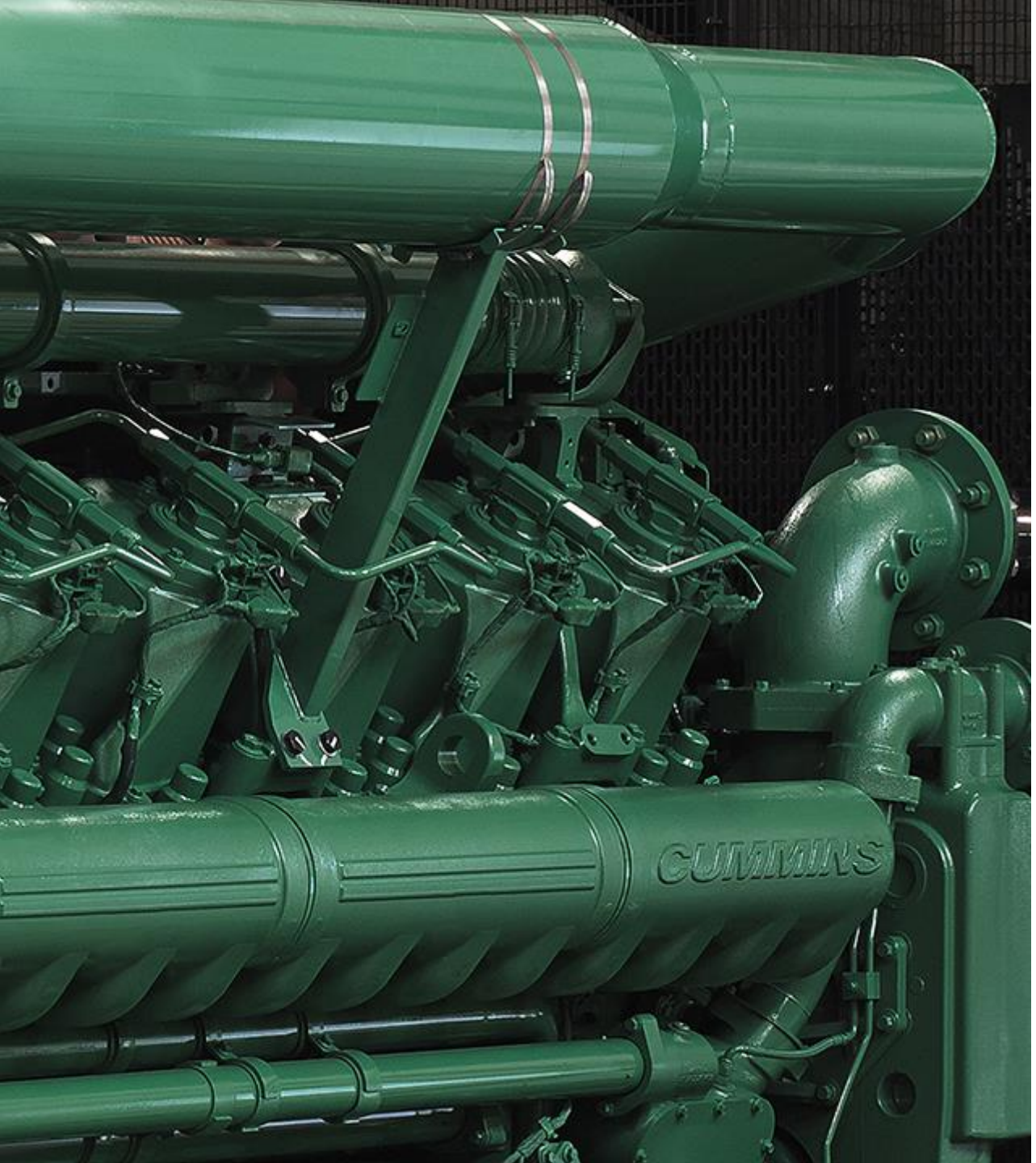

Specifying Gaseous Generator Sets

PowerHour webinar series for consulting engineers

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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

Specifying Gaseous Generator Sets

This course will provide of 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.

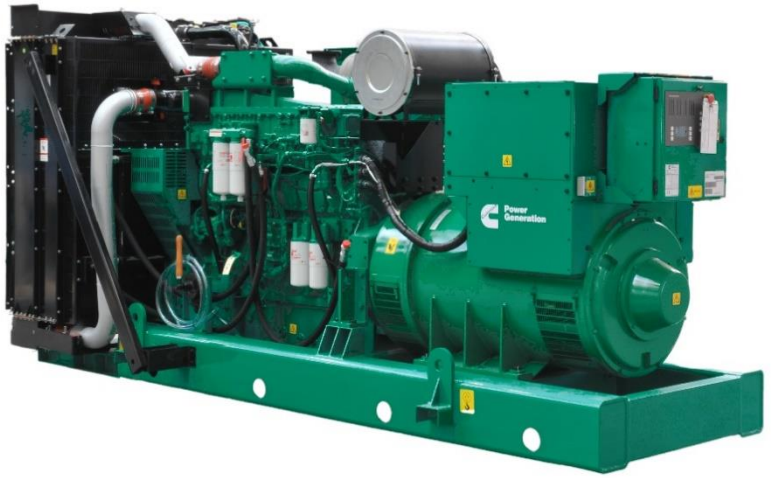
After completing this course, participants will be able to:

- 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

Energy Source	Energy Content [Btu]	Unit
Natural Gas	950-1150	1 ft^3
Propane gas	2250	1 ft^3
Propane Liquid Gas	91330	1 Gallon
Gasoline	124000	1 Gallon
Diesel Fuel	139000	1 Gallon



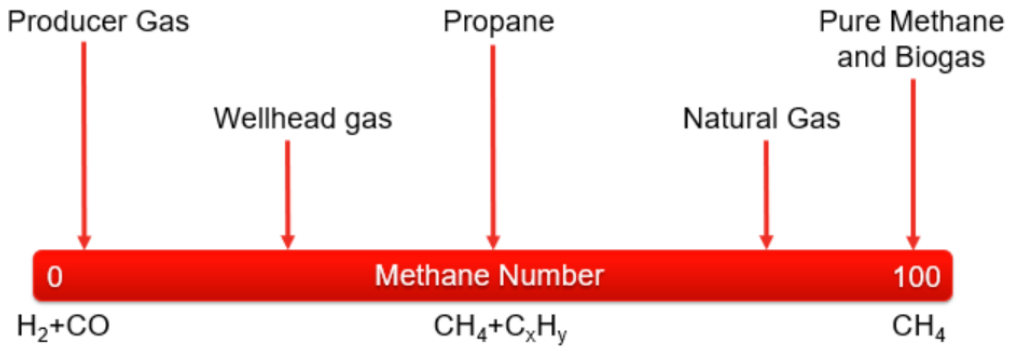
What is Gaseous Fuel?

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

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

	Load (percent of rated)		
100%	90%	75%	50%
62	60	60	60

Spec Note Include fuel composition when discussing with generator set manufacturer

Gaseous Generator Sets Types

	Rich Burn	Lean Burn
Air Fuel Ratio	~14.6 : 1	~25 : 1
Excess Air (O_2)	0.2 to 0.8%	>4%
Application	Fast start and can accept large block loads	High efficiency but requires advanced controls
Emissions	Aftertreatment may be required to reduce NOx and CO	Can often meet emissions requirements without aftertreatment

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.

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

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

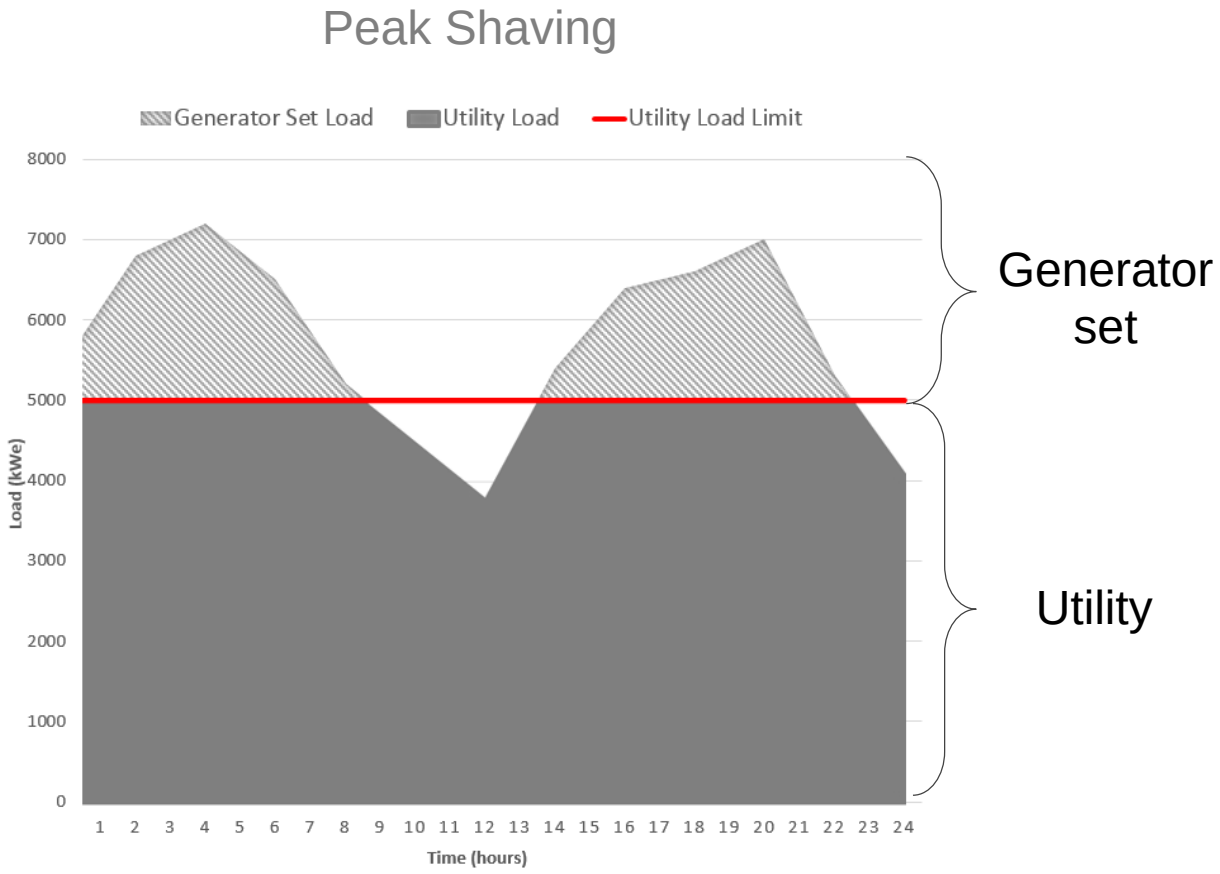
Table 4.1(b) Types of EPSSs

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

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

	NOx + NMHC	CO	PM
T3 Diesel 174 < HP < 751	4.0	3.5	0.2

	NOx	CO	PM
NG > 130 HP	2.0	4.0	-

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

kW	(hp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0-7	0-10	(7.5) / 8.0 / 0.40									
8-18	11-24	(7.5) / 6.6 / 0.40									
19-36	25-48	(7.5) / 5.5 / 0.30			(4.7) / 5.5 / 0.03 **Emergency: Previous tier**						
37-55	49-74	*Optional T4i 0.30 PM*			(4.7) / 5.0 / 0.03 **Emergency: Previous tier**						
56-74	75-99	(4.7) / 5.0 / 0.40		3.4 / 0.19 / 5.0 / 0.02 **Tier 3**			0.40 / 0.19 / 5.0 / 0.02 **Tier 3**				
75-129	100-173	(4.7) / 5.0 / 0.30		3.4 / 0.19 / 5.0 / 0.02 **Tier 3**			0.40 / 0.19 / 5.0 / 0.02 **Tier 3**				
130-560	174-751	(4.0) / 3.5 / 0.20	2.0 / 0.19 / 3.5 / 0.02 **Tier 3**			0.40 / 0.19 / 3.5 / 0.02 **Tier 3**					
> 560	> 751	(6.4) /3.5 / 0.20	3.5 / 0.40 / 3.5 / 0.10 **Tier 2** *0.67 / 0.40 / 3.5 / 0.10 (a)*				3.5 / 0.19 / 3.5 / 0.04 **Tier 2** *0.67 / 0.19 / 3.5 / 0.03 (b)*				

T2	T3	Tier 4 Interim	Tier 4 Final

Mandatory or Voluntary			HP	NOx/CO/VOC (g/bhp-hr) (NOx + HC) / CO (g/bhp-hr) 2015	2016	2017	2018	2019	2020
NG / LPG: Non-emergency									
V	NG	RB	26-99	1048 or for on- site ver. use 1048.101(c) for in- field test					
			>100	1.0 / 2.0 / 0.7					
	NG	LB	26-99	1048 or for on- site ver. use 1048.101(c) for in- field test					
			>100	1.0 / 2.0 / 0.7					
	LPG	LB	26-99	1048 or for on- site ver. use 1048.101(c) for in- field test					
			>100	1.0 / 2.0 / 0.7					
M	LPG	RB	>25	1048 cert: (2.7)/4.4					
Natural Gas / LPG: Emergency									
V	NG & LB LPG		26-129	90.103 phase 1 class II cert: (10) / 387					
			> 130	2.0 / 4.0 / 1.0					
M	LPG RB		26-129	90.103 phase 1 class II cert: (10) / 387					
			> 130	1048 full cert: 2.0 / 4.0 / 1.0					
Landfill / Digester Gas									
V	All LB & RB		All	2.0 / 5.0 / 1.0					

Engine Exhaust Pollutants

	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	✓	

PM and SOx 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:

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)

Concept Check

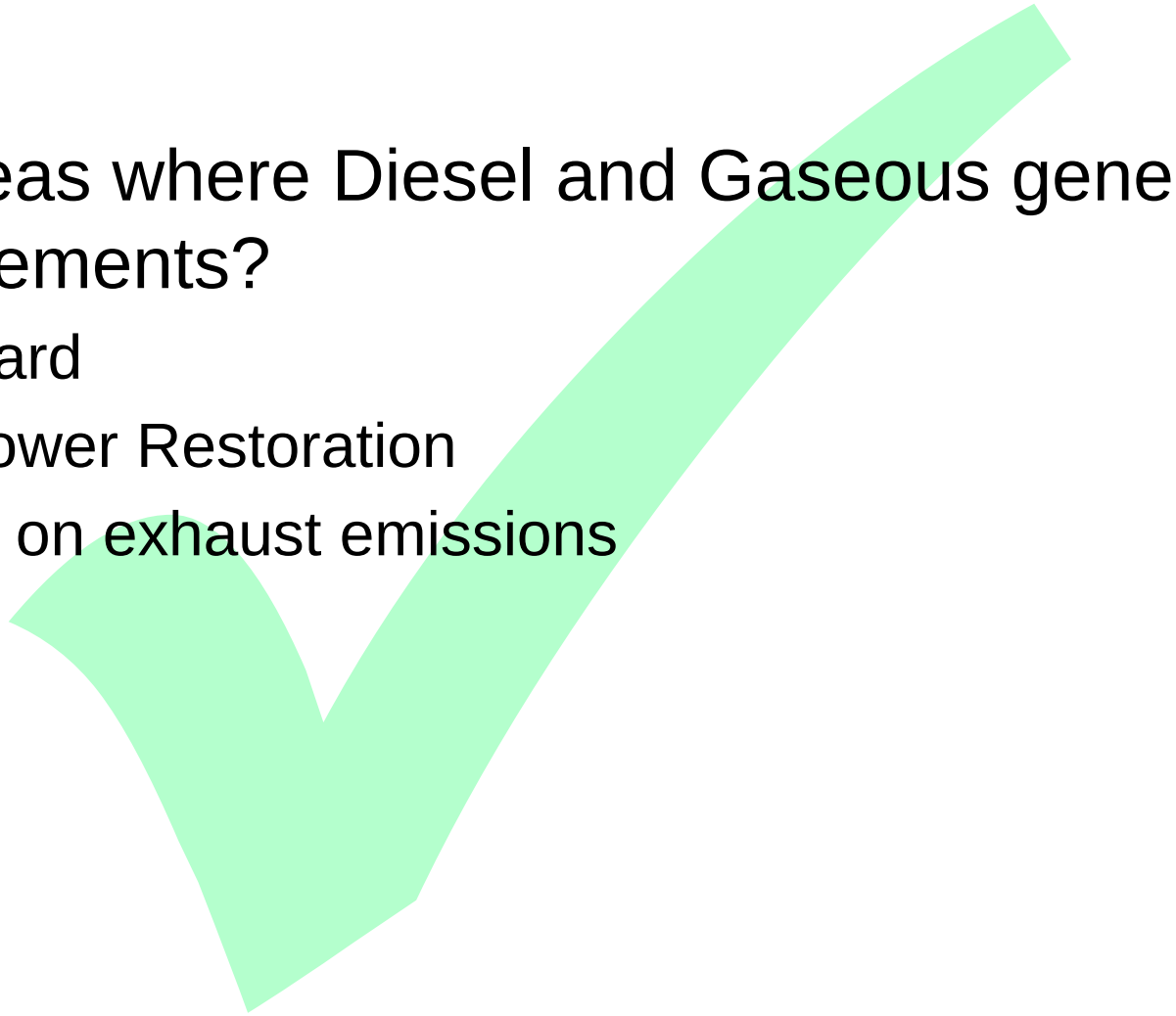
What are some areas where Diesel and Gaseous generator sets have similar requirements?

a) ISO 8528 standard

b) NFPA 110 for Power Restoration

c) EPA regulations on exhaust emissions

d) All of the above



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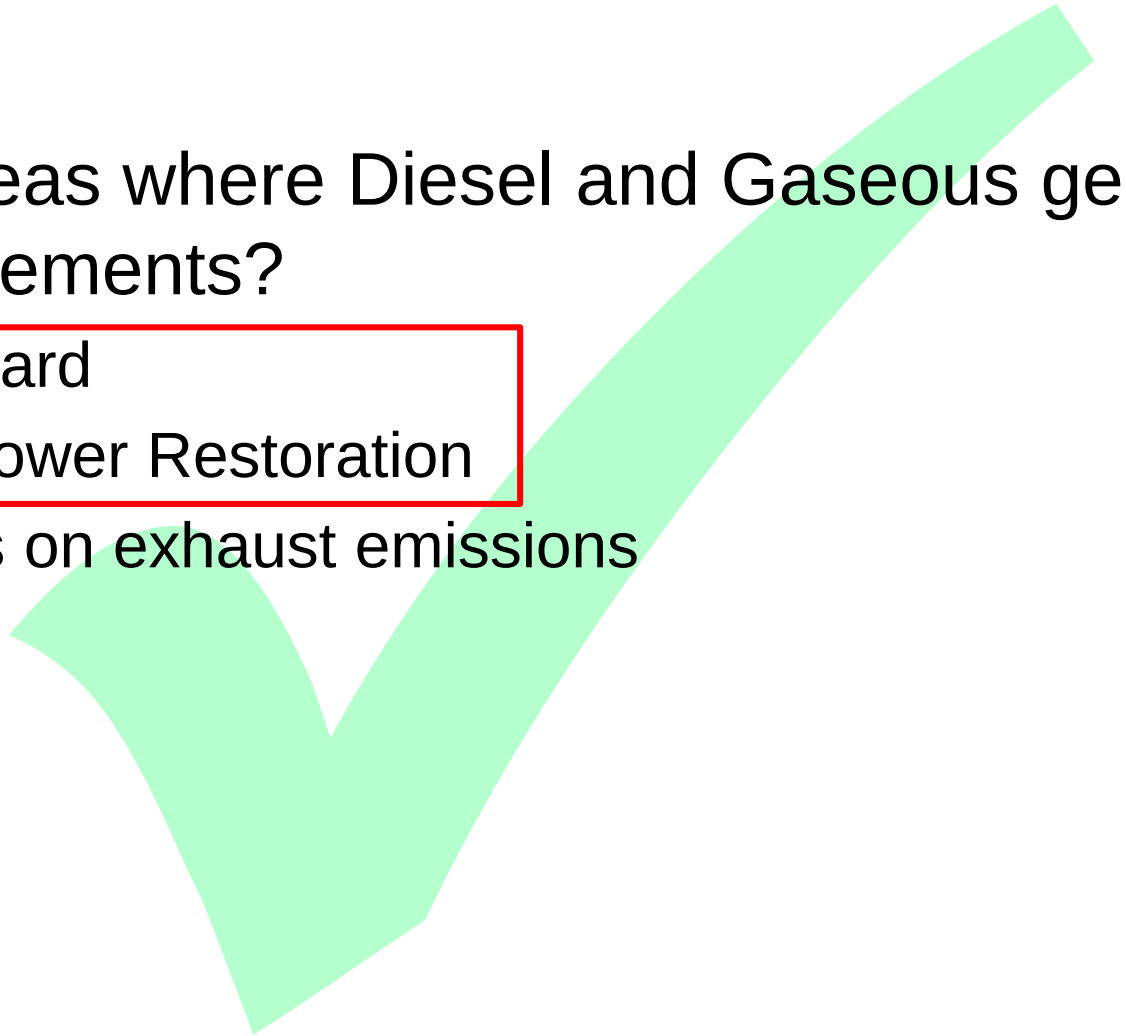


Installation Similarities

- 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

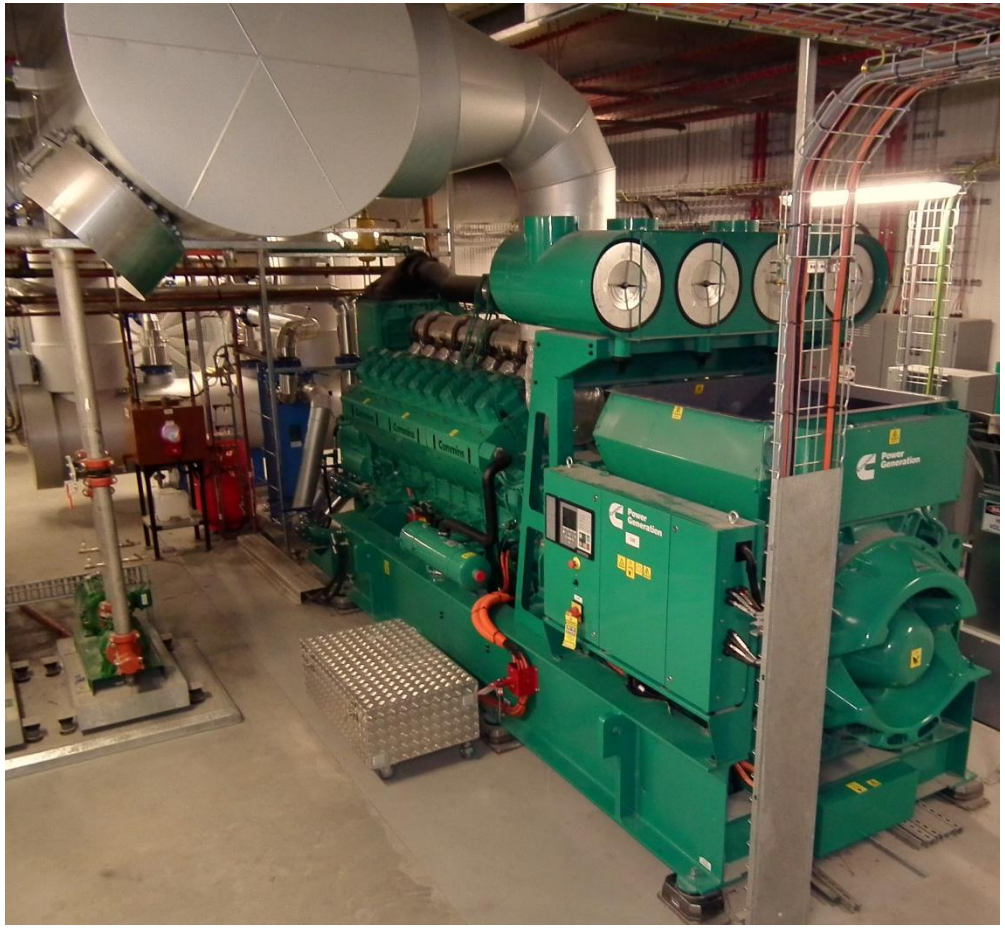
- Fuel problems cause ~70% of diesel engine failures
  - Microbial growth in storage tanks contributes ~90%
  - Heavy-end asphaltene becomes unstable and drops out of fuel
- Ultra Low Sulfur Diesel (ULSD) – recommend additional testing and fuel treatment

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



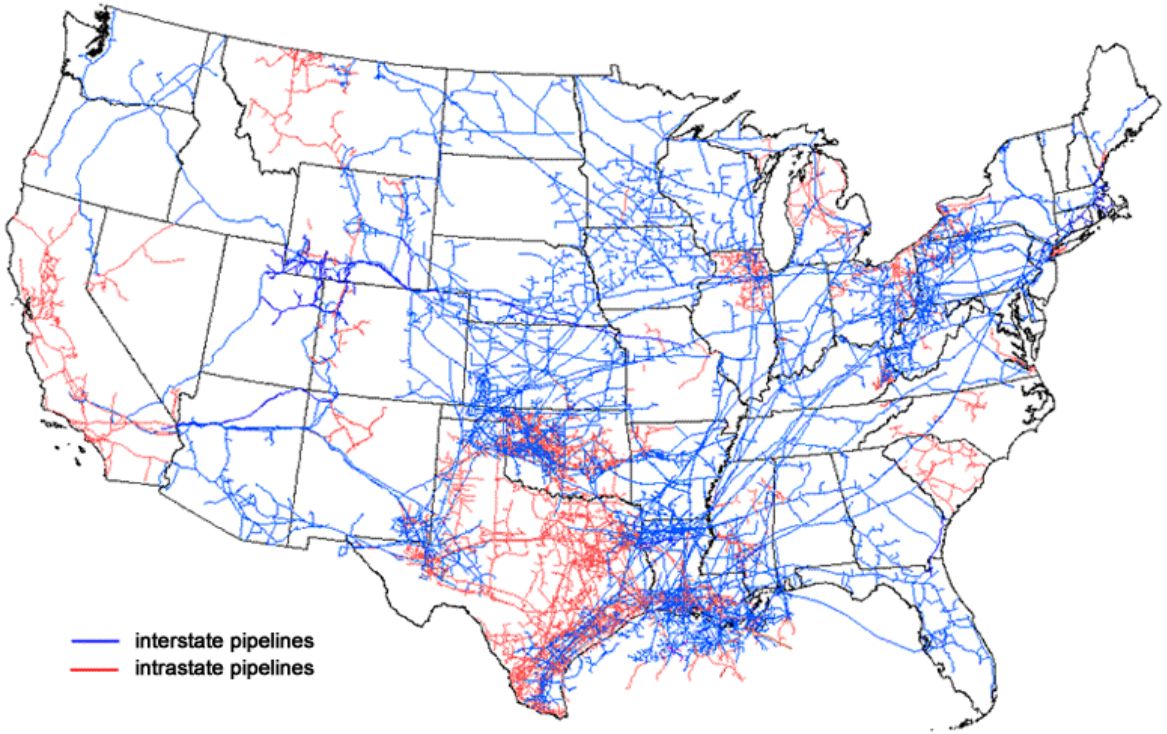
Gaseous Generators Sets Strengths

- 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*

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



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

www.government-fleet.com/15709/how-to-maintain-stored-diesel-fuel

Reliability of Natural Gas

Natural Gas Systems:
Reliable & Resilient

NATURAL GAS COUNCIL

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

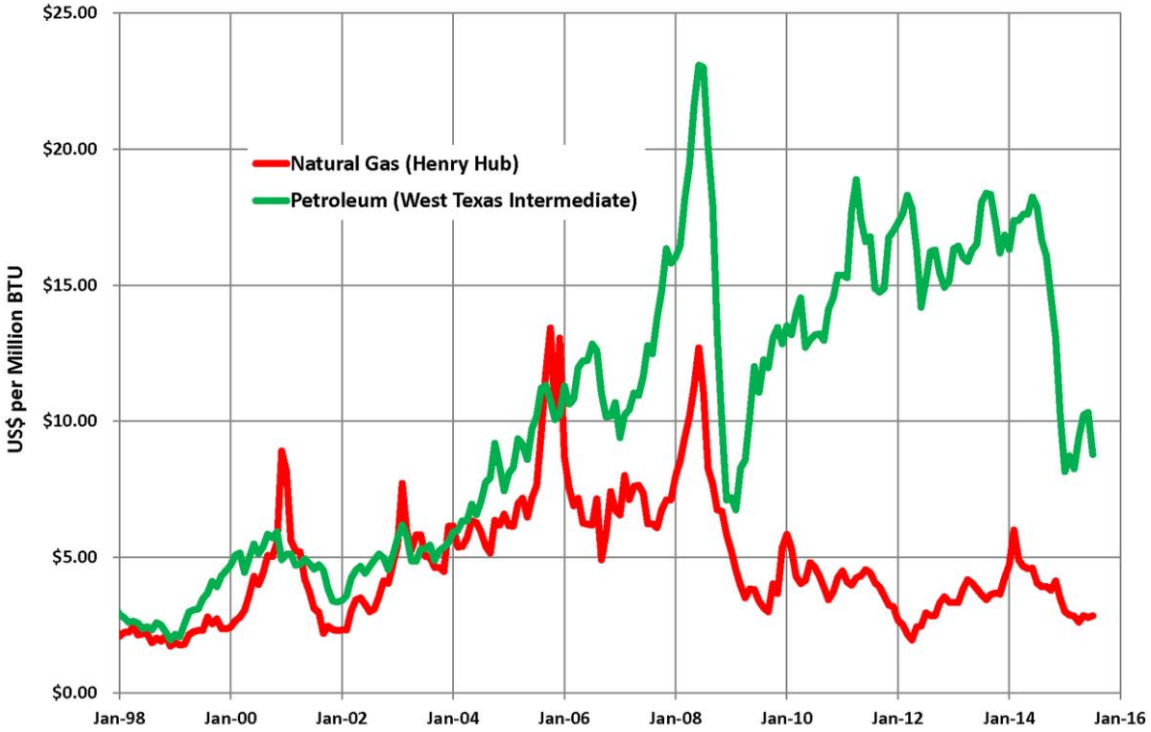
Natural gas is a secure, reliable and resilient choice for customers

- 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)

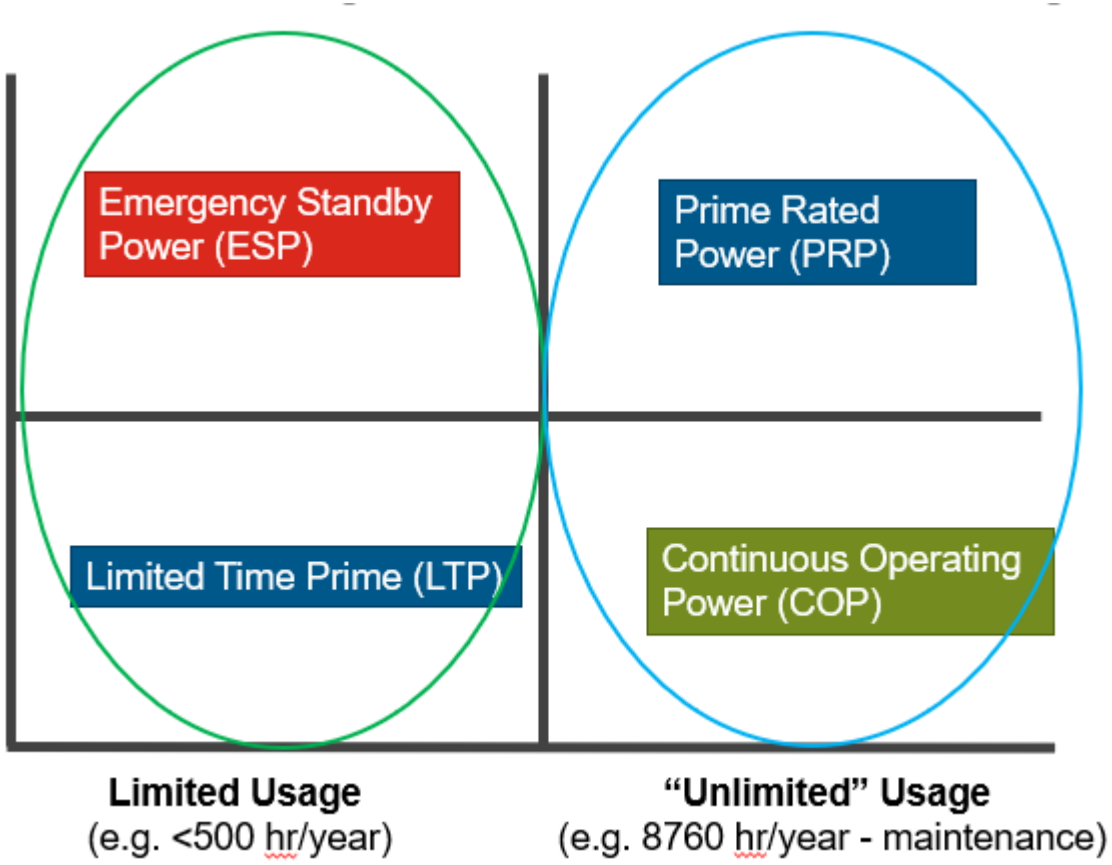


www.eia.gov/natrualgas

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



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

	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

Concept Check

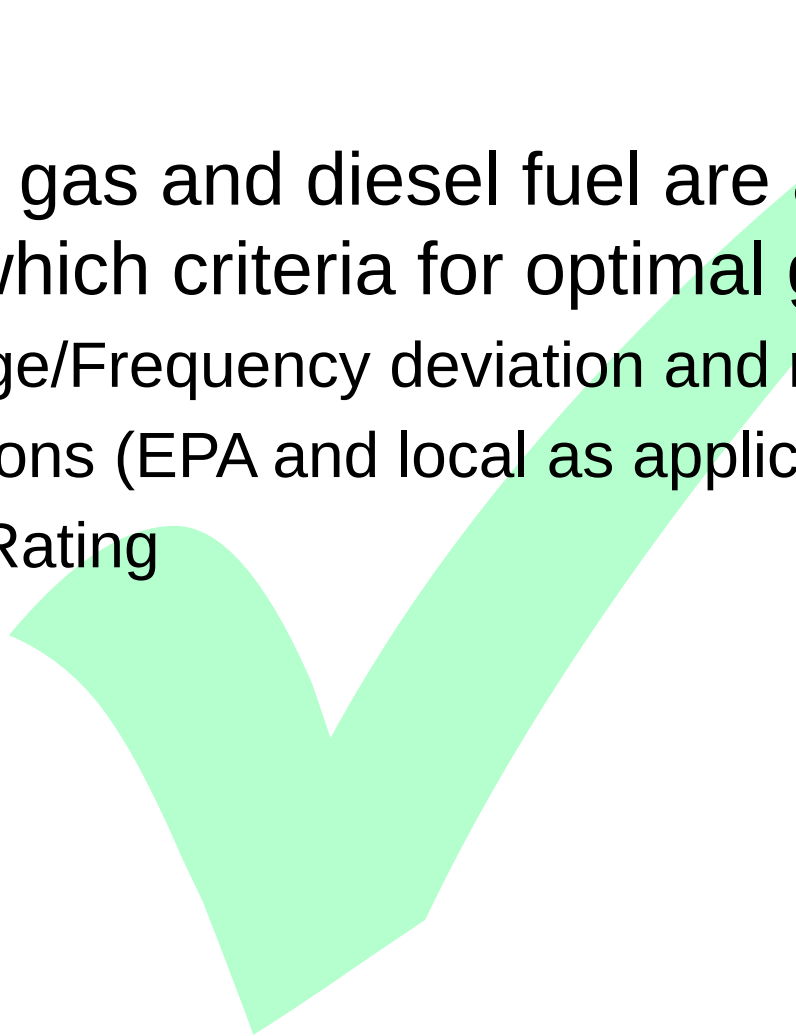
When both natural gas and diesel fuel are available for a project, it is best to specify which criteria for optimal generator set selection

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



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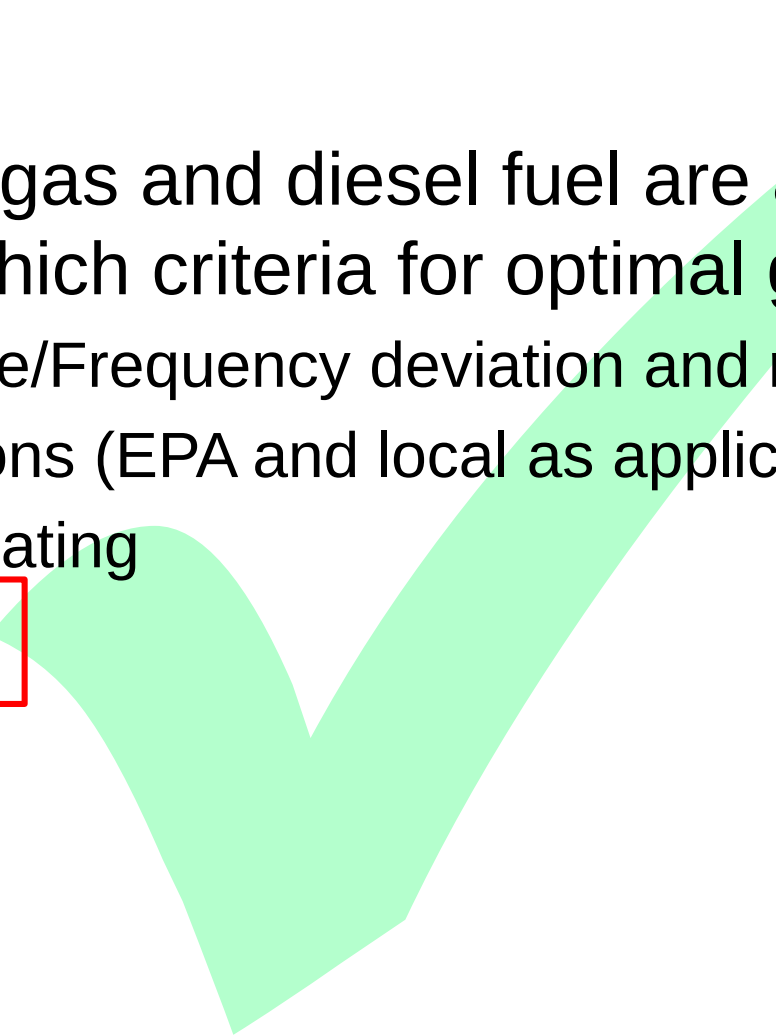


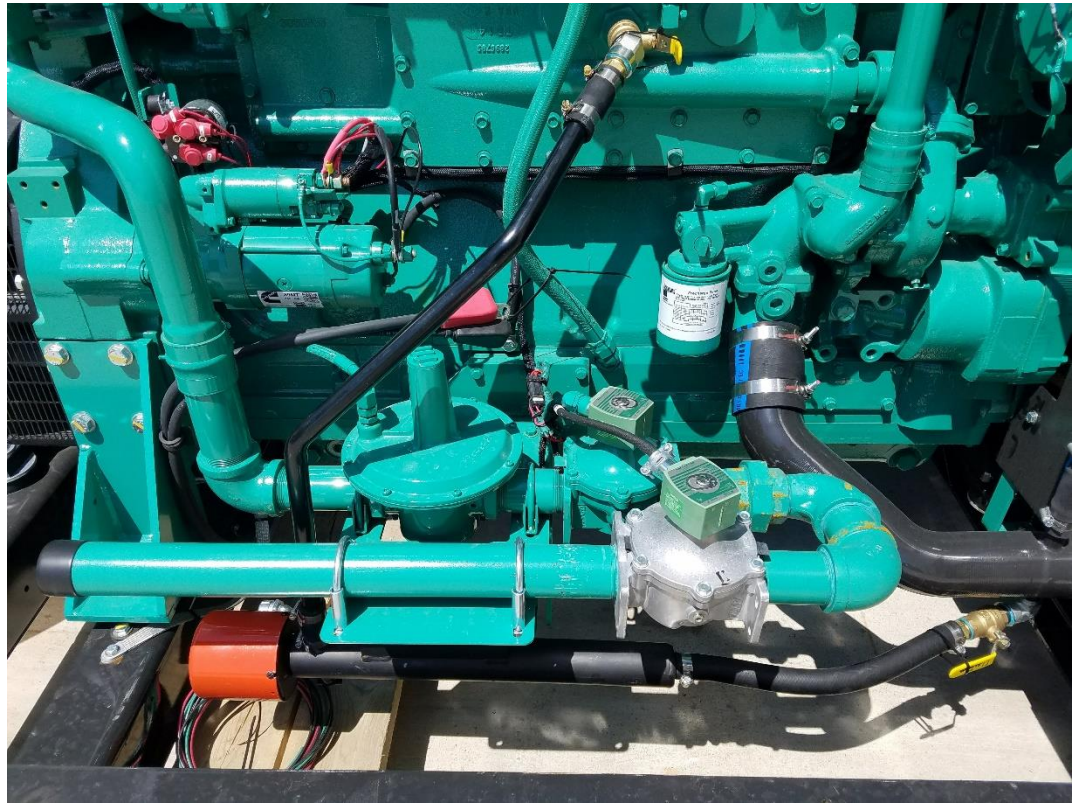
Selection Considerations

Standby	Diesel	Rich Burn	Lean Burn
Transient Performance	+	+	+/-
Reliability of Fuel Supply	-	+	+
Exhaust Emissions	-	+/-	+
Fuel Cost	-	+	+

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

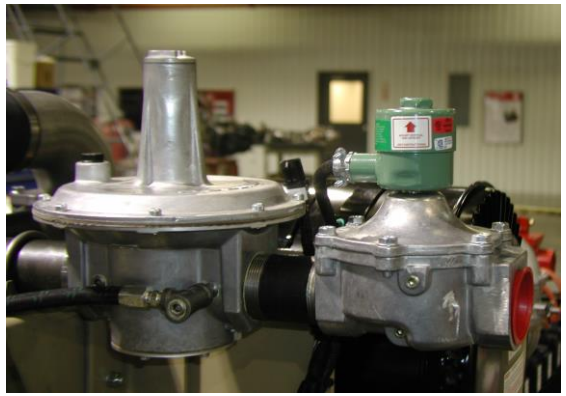
Gas supply pressure to engine inlet, bar (psi)[8]	0.2 (2.9)
Minimum methane index	62

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

Full Load Acceptance	Position (Note 1)								8-pos Ave.
	1	2	3	4	5	6	7	8	
T2 Diesel	89.5	91.6	91.2	92.3	88.9	91.7	92.6	91.4	91.3
RB NG	84.6	90.8	92.1	92.8	89.9	92.9	90.9	86.7	90.8

Note 1. Position 1 faces the Generator Set (GenSet) front per ISO 8528-10. The positions proceed around the GenSet in a counter-clockwise 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

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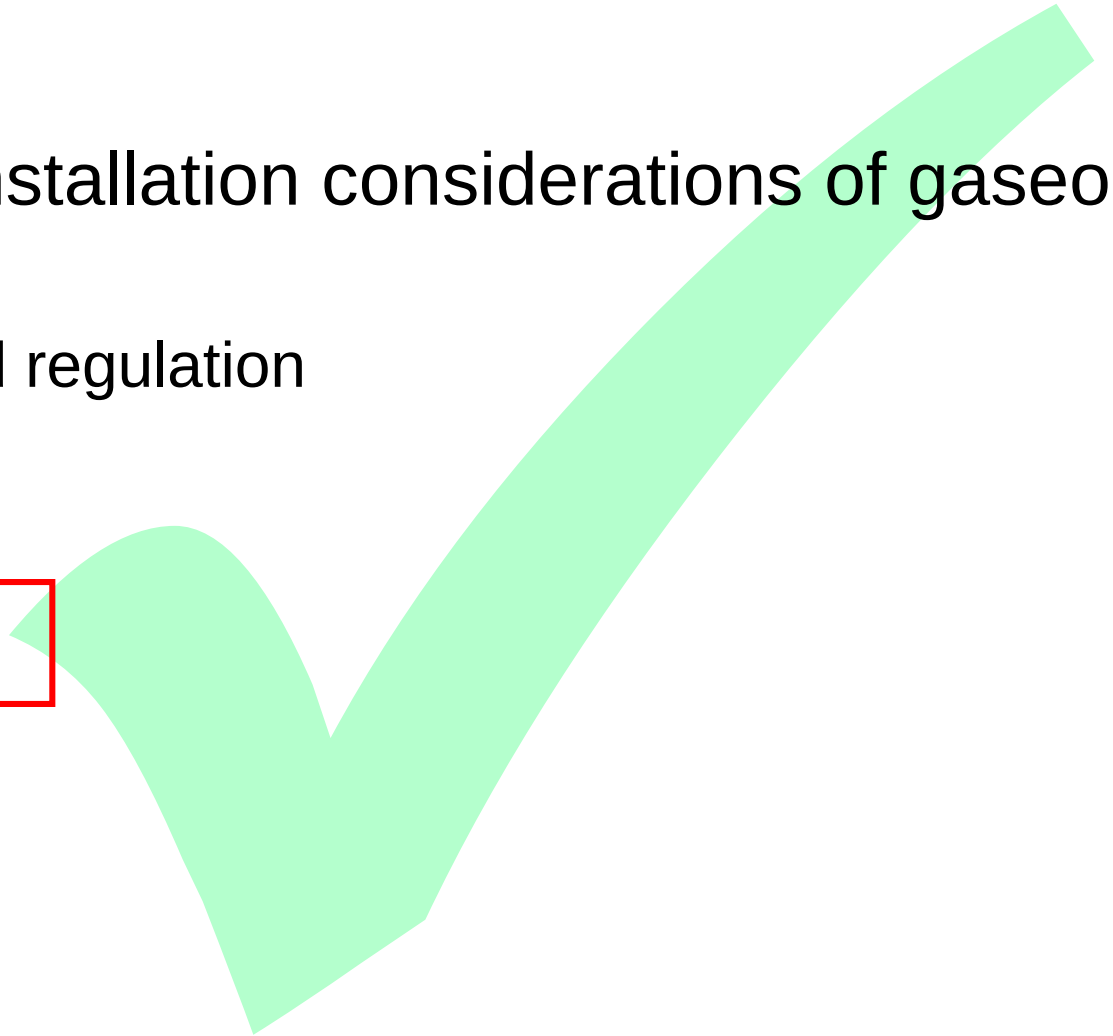

Course Summary

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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