Electric Power Technical Conference

October 2015
Tinaja Hills, AZ
Use of Gas Gensets in Standby Applications

Michael Devine
Introduction

• Mike Devine
  - EP Gas Product / Marketing Manager Caterpillar Energy Solutions
  - 40 years with Caterpillar
Agenda

• Differences between diesel and gas products
• How engines accept loads
• Factors effecting gas engine load acceptance
• Gas gen sets for Emergency Power Supply
• Why natural gas in standby
• Gas standby gen sets for distributed generation
• Maintaining gas gen sets for highest reliability
Differences Between Diesel and Gas Products

Diesel Generator Set (Tier 4)  Gas Generator Set
## Diesel and Gas Engines: How are they the same?

<table>
<thead>
<tr>
<th>System</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>Nearly identical</td>
</tr>
<tr>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>4 stroke cycle</td>
<td>Same</td>
</tr>
<tr>
<td>Air intake systems</td>
<td>Same</td>
</tr>
<tr>
<td>Exhaust systems</td>
<td>Same</td>
</tr>
<tr>
<td>Cooling systems</td>
<td>Similar two-circuit systems</td>
</tr>
</tbody>
</table>
Diesel and Gas Engines: How are they different?

• **Ignition system**
  Compression ignition vs. spark ignition

• **Fuel system**
  Direct injection vs. carbureted
Diesel Engines vs. Gas Engines

• Diesel Engine Demands - Structural
  – Engine structure must be robust enough to support high cylinder pressures
    • All injected fuel combusting at the same time
  – Fuel injection equipment must:
    • Produce high injection pressure
    • Meter fuel precisely
    • Introduce fuel at the correct moment
      (ignition timing = injection timing)
Diesel Engines vs. Gas Engines

- **Spark-Ignited Engine Demands - Thermal**
  - Inlet charge temperature rise must be regulated to control detonation
  - Engine components must be suited to withstand high exhaust temperatures
    - Constant air-fuel ratio makes for higher exhaust temperatures even at part load
  - Spark ignition equipment must:
    - Produce high ignition voltage
    - Create spark at the correct moment (ignition timing = spark timing)
Technology Differences

**Diesel Engines**
- Typically low hour

**Natural Gas Engines**
- Usually sees medium to high hour
## Technology Differences

<table>
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<td>• Higher initial installed cost than tier 2 diesel (similar to U.S. EPA Tier 4 certified diesel)</td>
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Technology Differences

**Diesel Engines**
- Typically low hour
- Lowest initial installed costs
- Lower efficiency

**Natural Gas Engines**
- Usually sees medium to high hour
- Higher initial installed cost than tier 2 diesel (similar to U.S. EPA Tier 4 certified diesel)
- Good Efficiency. Well suited for CHP applications
Technology Differences

**Diesel Engines**
- Typically low hour
- Lowest initial installed costs
- Lower efficiency
- Best starting and load acceptance

**Natural Gas Engines**
- Usually sees medium to high hour
- Higher initial installed cost than tier 2 diesel *(similar to U.S. EPA Tier 4 certified diesel)*
- Good Efficiency. Well suited for CHP applications
- Some models match diesel starting capabilities. Good transient performance
Gas Engine Combustion Technologies

Rich Burn or Stoichiometric Combustion

Lean Burn Combustion

Total Exhaust 100%

Stoichiometric Mixture

Fuel

Air

Excess Air

O₂
NO\textsubscript{x} Characteristic

- Slower combustion
- Lean fuel mixture is harder to ignite
- Lean misfire

Lack of O\textsubscript{2}

O\textsubscript{2} (% Dry)  NO\textsubscript{x} (g/hp-hr)

Rich Burn  Lean Burn

LAMBDA
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Tier 4 “Emergency” Use Definition

• Non Tier 4 certified product can be sold
  – Certified to Tier 2 emissions levels - No aftertreatment

• Can use retrofit aftertreatment but emergency application guidelines & hour restrictions still apply

• True “Prime” (non-emergency) or ‘non-road mobile’ EP applications must use Tier 4 certified product

SCR for emissions control
~ 40% cost increase
# Budgeting Emergency Power Systems

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Diesel</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Generator Set ($/kW)</td>
<td>$250</td>
<td>$350</td>
</tr>
<tr>
<td>Mech. &amp; Structural¹ ($/kW)</td>
<td>$200</td>
<td>$190</td>
</tr>
<tr>
<td>Electrical² ($/kW)</td>
<td>$118</td>
<td>$118</td>
</tr>
<tr>
<td>Startup-Commissioning³ ($/kW)</td>
<td>$13</td>
<td>$11</td>
</tr>
<tr>
<td>Freight &amp; Logistics⁴ ($/kW)</td>
<td>$5</td>
<td>$5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$586</strong></td>
<td><strong>$674</strong></td>
</tr>
</tbody>
</table>

Assumptions based on 1000kW generator (EPA Tier 2 Diesel, EPA NSPS SI Gas)

1. Mechanical includes **outdoor enclosure**, fuel tanks or gas train, exhaust/silencer, radiator, air filters, contractor installation
2. Electrical includes **switchgear**, communications, cable & conduit, batteries, breakers, contractor installation
3. Commissioning includes fuel, coolant, oil, technician service, project management, basic customer training
4. Freight includes shipment of all components
5. Values are reference only
How Engines Accept Loads
Diesel engines have excess air in the cylinder. When more power is needed, more fuel is injected into the cylinder.

This can happen very quickly.
How Diesel Engines Accept Load

Diesel Fuel System Diagram

System loses speed, calls for more power
How Diesel Engines Accept Load

Unit injector atomizes fuel into hot air

Diesel Fuel System Diagram
How Diesel Engines Accept Load

Which drives more air to the cylinder

Heated exhaust air turns turbo faster…

Diesel Fuel System Diagram
How Gas Engines Accept Load

- Gas engines need to mix the air and fuel together before it gets to the cylinder
- This takes a lot more time (relatively speaking)
How Gas Engines Accept Load

G3500C/E Low Pressure Gas Fuel System

System loses speed, calls for more power
How Gas Engines Accept Load

Throttle opens up to let more air/fuel in

G3500C/E Low Pressure Gas Fuel System
How Gas Engines Accept Load

G3500C/E Low Pressure Gas Fuel System
How Gas Engines Accept Load

G3500C/E Low Pressure Gas Fuel System
Comparing Diesel and Gas Ratings
Emergency Standby Power (ESP)
Output available with varying load for the duration of an emergency outage. Average power output is 70% of the emergency standby power rating. Typical operation is 50 hours per year with maximum expected usage of 200 hours per year.

Standby Power
Output available with varying load for the duration of the interruption of the normal source power. Average power output is 70% of the standby power rating. Typical operation is 200 hours per year, with maximum expected usage of 500 hours per year.

Mission Critical Standby Power
Output available with varying load for the duration of the interruption of the normal source power. Average power output is 85% of the standby power rating. Typical operation is 200 hours per year, with maximum expected usage of 500 hours per year.
Diesel vs Gas Operating Criteria

**Diesel Generator Set**
- Emergency Standby Power
- Standby Power
- Mission Critical Power

**Gas Generator Set**
- Gas engine will be continuous rated
  - Detonation limited
  - Exhaust temp limited
    - No overload available
- Generator and other ancillary equipment may be standby rated
Generator Rating Levels

Generators are rated based upon the service they are designed / expected to deliver.

<table>
<thead>
<tr>
<th>Generator Class</th>
<th>Temperature Rise °C</th>
<th>Genset Package Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>80</td>
<td>Continuous</td>
</tr>
<tr>
<td>H</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>F</td>
<td>105</td>
<td>Prime</td>
</tr>
<tr>
<td>H</td>
<td>125</td>
<td>Prime</td>
</tr>
<tr>
<td>F</td>
<td>130</td>
<td>Standby</td>
</tr>
<tr>
<td>H</td>
<td>150</td>
<td>Standby</td>
</tr>
</tbody>
</table>
Factors Effecting Gas Engine Loading
Factors Effecting Gas Engine Load Acceptance

Most critical customer requirements effecting engine loading design considerations (standby -island mode) are:

- Required % load accept
- Required % load rejected
- Allowable frequency dip
  - For both load acceptance and load rejection
- Allowable voltage dip
  - For both load acceptance and rejection
- Allowable recovery time
Factors Effecting Gas Engine Load Acceptance

Plugged or Size Restricting Fuel Filter

Fuel Pressure

Fuel line Restriction

Air Restriction

Exhaust Restriction

Emissions level effects the a/f ratio, volume required

G3500C/E Low Pressure Gas Fuel System
## G3500C Platform Transient Performance

<table>
<thead>
<tr>
<th>Load Step</th>
<th>Dynamic Frequency Deviation</th>
<th>Dynamic Voltage Deviation</th>
<th>Recovery Time to SS</th>
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<tbody>
<tr>
<td>25%</td>
<td>+/- 16%</td>
<td>+/- 12%</td>
<td>20 Sec</td>
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<tr>
<td>25%*</td>
<td>+/- 10%</td>
<td>+/- 12%</td>
<td>10 Sec</td>
</tr>
<tr>
<td>10%</td>
<td>+/- 5%</td>
<td>+/- 3%</td>
<td>5 Sec</td>
</tr>
<tr>
<td>5%</td>
<td>+/- 2.5%</td>
<td>+/- 1%</td>
<td>5 Sec</td>
</tr>
<tr>
<td>SS</td>
<td>+/- 1%</td>
<td>+/- 1%</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Valid for block loads above the initial 25% load step*
# G3500C Platform Transient Performance

<table>
<thead>
<tr>
<th>1st Load Step</th>
<th>Dynamic Frequency Deviation</th>
<th>Dynamic Voltage Deviation</th>
<th>Recovery Time to SS</th>
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<tr>
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<td>+/- 1%</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Valid for block loads above the initial 25% load step*
### Block Loads

#### First 50% Step

<table>
<thead>
<tr>
<th></th>
<th>Start load</th>
<th>Finish load</th>
<th>Time to be within ±2.5% of rated Freq (± 1.5 Hz)</th>
<th>9.4 seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>580</td>
<td>Time to be within ±5% of rated Freq (± 3 Hz)</td>
<td>3.9 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±10% of rated Freq (± 6 Hz)</td>
<td>2.7 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±2.5% of rated Voltage (± 12 V)</td>
<td>9.8 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±5% of rated Voltage (± 24 V)</td>
<td>4.3 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±10% of rated Voltage (± 48 V)</td>
<td>3.5 seconds</td>
</tr>
<tr>
<td>Minimum Voltage Recorded</td>
<td>363.2 Volts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Voltage Recorded</td>
<td>480.8 Volts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Frequency Recorded</td>
<td>51.0 Hertz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Frequency Recorded</td>
<td>60.2 Hertz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Second 50% Step

<table>
<thead>
<tr>
<th></th>
<th>Start load</th>
<th>Finish load</th>
<th>Time to be within ±2.5% of rated Freq (± 1.5 Hz)</th>
<th>3.9 seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>580</td>
<td>1180</td>
<td>Time to be within ±5% of rated Freq (± 3 Hz)</td>
<td>3.5 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±10% of rated Freq (± 6 Hz)</td>
<td>1.6 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±2.5% of rated Voltage (± 12 V)</td>
<td>4.3 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±5% of rated Voltage (± 24 V)</td>
<td>3.9 seconds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to be within ±10% of rated Voltage (± 48 V)</td>
<td>2.7 seconds</td>
</tr>
<tr>
<td>Minimum Voltage Recorded</td>
<td>404.0 Volts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Voltage Recorded</td>
<td>480.9 Volts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Frequency Recorded</td>
<td>54.1 Hertz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Frequency Recorded</td>
<td>60.1 Hertz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 24.3% Time to stabilize
- 15.0% Time to stabilize
- 15.8% Time to stabilize
- 9.8% Time to stabilize
Ramp Loading

1600 kW
13.3% V Dip
8.8% Freq Dip

| Start load | 0 kW |
| Finish load | 1600 kW |
| Time to be within ±2.5% of rated Freq (± 1.5 Hz) | 11.7 seconds |
| Time to be within ±5% of rated Freq (± 3 Hz) | 10.9 seconds |
| Time to be within ±10% of rated Freq (± 6 Hz) | ≥ 120 seconds |
| Time to be within ±2.5% of rated Voltage (± 12 V) | 13.3 seconds |
| Time to be within ±5% of rated Voltage (± 24 V) | 11.3 seconds |
| Time to be within ±10% of rated Voltage (± 48 V) | 10.2 seconds |
| Minimum Voltage Recorded | 416.5 Volts |
| Maximum Voltage Recorded | 481.1 Volts |
| Minimum Frequency Recorded | 54.7 Hz |
| Maximum Frequency Recorded | 60.1 Hz |
Factors Effecting Gas Engine Load Acceptance

To meet user needs, NFPA110 states:

**Transient Response**

- **Frequency Dip:** Frequency dip upon one-step application of the full load shall not be outside the range for the load…”

- **Frequency Dip:** “Frequency dip and restoration to steady state for any sudden load change shall not exceed the user’s specified need”

- **Voltage Dip:** “Voltage dip at the generator terminal for the maximum anticipated load change shall not cause disruption or relay dropout in the load”

**Critical Customer Requirements**

- Required % load accept
- Required % load rejected
- Allowable recovery time
- Allowable frequency dip
  - For both load acceptance and load rejection
- Allowable voltage dip
  - For both load acceptance and rejection

If you really want to employ a gas generator set successfully on your project, you may need to ‘negotiable’ on one or more of the CCR’s.
Emergency Power Supply
Gas Generator Sets
Can You Depend on the Grid?
South Carolina Flood- October 2015

Columbia, SC
Source: Fox 13

Richland County, SC
Source: Baynews 9
Power Supply Security

- Existing critical infrastructure power supply strategies reflect historical risks and recovery experience

After Mills and Huber, “Critical Power” white paper, [www.digitalpowergroup.com](http://www.digitalpowergroup.com), August 2003
Power Supply Security

- Existing critical infrastructure power supply strategies reflect historical risks and recovery experience

Emergency Power Supply Gensets

Example Loads:
- Egress Lighting
- Elevators
- Fire Detection / Alarm
- Fire Pumps

Equipment Protecting People Leaving a Building ≤10 Seconds Without Power
Emergency Power Supply Gensets

Utility

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Emergency Systems

- Example Loads:
  - Egress Lighting
  - Elevators
  - Fire Detection / Alarm
  - Fire Pumps

- Equipment Protecting People Leaving a Building
  - ≤10 Seconds Without Power

---

Legally Required Standby

- Example Loads:
  - Communications Equipment
  - Smoke Removal Equipment
  - Ventilation
  - Sewage Removal Systems
  - Industrial Equipment (Safety)

- Equipment Aiding Rescue Workers & Mandatory Building Functions
  - ≤60 Seconds Without Power

---

NEC:

- Shall not be solely reliant on public fuel source (gas line) for fuel supply
- unless acceptable to AHJ
Fuel Security

- May 2013 study commissioned by the DOD
- Determine the reliability of the US natural gas infrastructure
- Study backs the premise that the natural Gas infrastructure could be considered on site storage in many instances
  - Few single points of failure for system wide collapse
  - Superior run time capability compared to diesel

*Source: “Interdependence of the Electricity Generation System and the National Gas System and Implications For Energy Security”

**Prepared by Lincoln Laboratory Massachusetts Institute of Technology for the Office of the Secretary of Defense under Air Force Contract FA8721-05-C-0002.**
Emergency Power Supply Gensets

**Emergency Systems**
- Example Loads:
  - Egress Lighting
  - Elevators
  - Fire Detection / Alarm
  - Fire Pumps
- ≤10 Seconds Without Power
- Equipment Protecting People Leaving a Building

**Legally Required Standby**
- Example Loads:
  - Communications Equipment
  - Smoke Removal Equipment
  - Ventilation
  - Sewage Removal Systems
  - Industrial Equipment (Safety)
- ≤60 Seconds Without Power
- Equipment Aiding Rescue Workers & Mandatory Building Functions

**Optional Standby Systems**
- Example Loads:
  - Data Equipment
  - Refrigeration Equipment
  - Optional Lighting
  - Industrial Equipment
  - Other not legally required applications
- Does Not Protect People, Protects Business

**NEC:**
- Shall not be solely reliant on public fuel source (gas line) for fuel supply, unless acceptable to AHJ

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CAT
Emergency Power Supply GenSet

**Targeted Application:**
- Emergency standby
- Legally required standby
- Optional standby systems

**Backup Power For:**
- Office buildings/complexes
- Industrial facilities
- Data centers
- Retail complexes
- Schools
- Government buildings
- Universities
- Research facilities
- Etc.

**Critical Customer Requirements:**
- Transient response
- Fast start time and load acceptance
- Low installed cost
- Performance reliability
- $2g/hp-h NO_x$, $4g/hp-h CO$, $1g/hp-h VOC$

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1500 kW Standby
Why Gas Generator Sets in Standby?
Why Natural Gas in Standby?

- Fuel Availability
  - Diesel supply can be weak link under certain conditions
- Emissions
  - High availability of gas
- No Diesel Storage Tank
  - Low risk of fuel contamination
- Application Flexibility

[Image of natural gas equipment]
Why Natural Gas in Standby?

- **Fuel Availability**
- **Emissions**
- **No Diesel Storage Tank**
- **Application Flexibility**

### NSPS emergency standby without aftertreatment
- Emissions limits for emergency applications
  - \(2g/bhp-h \text{ NO}_x\), \(4g/bhp-h \text{ CO}\), \(1g/bhp-h \text{ VOC}\)
- Local codes may require lower emissions
- There are many engine emissions settings at \(1g/bhp-hr\) and below available without the need for aftertreatment

![500 kW Standby](image)
Why Natural Gas in Standby?

- Fuel Availability
- Emissions
- No Diesel Storage Tank
- Application Flexibility

- Code requirements limit or restrict diesel storage in some instances / areas
- No fuel treatment required
Why Natural Gas in Standby?

- **Fuel Availability**
  - Fuel cost savings with gas
    - For 100 hrs of operation at 1.5MW, fuel cost savings approach $34,000 *

- **Emissions**

- **No Diesel Storage Tank**

- **Application Flexibility**
  - Demand response capable
    - For non-life safety applications
    - When equipped for continuous duty

* Comparison based on a G3516C ($4.5/mmBtu) vs. 3512C ATAAC ($3.87/gal)

Duck graph courtesy of CAISO (caiso.com)
Key Demand Response Market Driver: Spark Spread

Spark Spread = CHP Business Case

Source = US DOE Energy Information Administration
Load Management

Utility Load Duration Curve

$750/MW-hr

$40/MW-hr

$20/MW-hr

Time

(Load Distribution Over 12 Month Period)

KWh

Base Load Resource

Intermediate Resources

Peaking Resources

Peaking with Gas Resource

Peaking with Diesel Resource
Demand Response Market
Load Management Genset

Targeted Application:
- Peak shaving
  - 100% load factor
  - 500 – 4000+ hours per year
  - Hours limited by spark spread

Peaking Power For:
- Commercial facilities
- Shopping centers
- Industrial facilities
- Data centers
- Government buildings
- Universities
- Utilities
- Etc.

Critical Customer Requirements:
- **Fuel efficiency** is more important than for EPS
  - Level of efficiency driven by gas price and number of operating hours
- Performance reliability
- Maintenance and overhaul costs
- Project pro forma
- 1g/hp-h NO\textsubscript{x}, 2g/hp-h CO, .7g/hp-h VOC

2000 kW Standby and Peak Shaving
Efficiency vs. Installed Cost

Efficiency is worth more when fuel costs are higher and run timer are longer.

Critical Customer Requirements
- Low Operating Cost
- High Uptime

Gas OPEX Product
G3500H

Critical Customer Requirements
- Low Installed Cost
- High Reliability

Gas CAPEX Product
G3512/16 CAPEX Products

Spark Spread Gap
Fuel Price
Electric Rate / Cost
+ Incentives (if applicable)
Inverse of Critical Customer Requirements (CCRs) from Standby to Continuous Duty

CCRs – EP Standby

- Load Response
- Start-To-Load Time
- Price
- Power Density

CCRs – EP Continuous

- Efficiency
- Durability (8000+ hr/yr)
- Fuel Tolerance

- Load Response
- Price
- Start to Load Time
- Power Density

Importance ➔
Many Electric Utilities Use Gas Generator Sets For Peaking...

Natural gas engines have the ability to provide utility peaking capabilities and system standby.
Cat Gas Packages

- Packaged generator sets designed to meet site requirements
- Modules are transportable
- Similar in concept to power module
Criteria for Standby Segments

• Hospitals, high rise buildings…
  – ‘Emergency Systems’
    • Life safety- egress from a building
  – Generator sets can be only used for the emergency circuits that it is designed to protect.
  – No peaking or other use is allowed
Emergency Systems Power
Generator Set Performance Parameters

**Electrical Power:**
- 500kW, 750 kW, 1MW, 1.5MW, 2MW

**Emissions:**
- **EPA Certified:**
  - 2g/hp-h NOx, 4g/hp-h CO, 1g/hp-h VOC
- Lower NOx Settings Available *

**Transient Response:**
- **NFPA 110 Level 1 Applications**
- Load Steps ≤ 60%: ISO 8528/5 G2
- Load Steps > 60%: ISO 8528/5 G1
- **100% Block Load Capability:** Recovery ≤ 10 Seconds
- Steady State Voltage Deviation: ± 0.5 %
- Steady State Frequency Deviation: ± 0.5 %
- Time to Genset Start & Ready to Accept Load: **6.5 Seconds**

**Fuel:**
- 70-100 Cat Methane Number
- Min Low Heating Value: ≤ 800 Btu/scf
- Min Fuel Pressure at Fuel Control Valve: ≤ 0.5 psi.
- Max Fuel Pressure Variation: ≥ ±10%
- Max Rate of Fuel Pressure Variation: ≥ .29 psi./sec

**Generator:**
- LV Temperature Rise: ≤ 150°C Temp Rise/40°C Ambient
- HV Temperature Rise: ≤ 130°C Temp Rise/40°C Ambient
- Electrical Pitch: 2/3 Pitch

* Lower NOx levels may effect performance capabilities
Emergency Power – Development Standards

Applicable Standards & Regulations

**Genset:**
- UL 2200 (Low Voltage Only)
- NFPA110
- NFPA 37
- NFPA 70
- CSA 282-00 (Low Voltage Only)
- CSA B149.1
- ISO 8528-1
- ISO 8528-5
- ISO 9001

**Engine:**
- ISO3046
- ISO8528-2

**Generator:**
- NEMA MG1
- ISO 8528-3
- UL 1446
- IEC 60034 (IP-22)
- MIL 461-C
- CSA 22.2
Criteria for Standby Segments

• Data centers, office buildings, shopping centers, electric utilities...
  – ‘Legally required standby’ or ‘Optional standby systems’
  – System designed for demand response first, standby if needed
    • Standby would be a switchgear change only
Maintaining Gas Generator Sets for Highest Reliability
Maintain Systems for Highest Reliability

Long term system reliability is dependent upon a rigorous preventative maintenance plan.
General Maintenance Considerations

• **Common causes of failure to start:**
  - Discharged batteries
  - Not in Auto/E-stop
  - No fuel/bad fuel
  - Low fluid levels/filter contamination
Condition Monitoring

“Processes that facilitate timely and accurate detection of changes in equipment health, operation and application severity in support of a repair before failure maintenance strategy.”
Condition Monitoring

- Understand the monitored process
- Normalized readings
- Focus on changes occurring over time and trend
- End State: Scheduled repairs instead of unplanned downtime

Time to schedule downtime and repair of the generator
Design for Service and Maintenance

- Designs better match power need and equipment capability
- Have a plan for unplanned events – Disaster Preparedness
  - Rental contingency
  - Quick coupling – Rental gen and load bank
  - Equipment first right of refusal
  - Maintenance plans
    - Needed for any long term outage
    - Covered for any scheduled maintenance

Generator Quick-Connect Box
What is the Duration of an Outage?

Outages can last from seconds to weeks or more

- Mt. St. Helens, May 18, 1980
  - Power disruptions for over a year in some areas

- Hurricane Ike, September 13, 2008
  - 1 million outages in Texas one week after landfall, power fully restored on October 6*
    - 23 days / 552 hours

- Hurricane Sandy, October 29, 2012
  - 8.5 million outages at peak
    - Power fully restored on November 19*
    - 22 days / 528 hours

*U.S. Department of Energy Office of Electricity Delivery & Energy Reliability
**Maintenance in the Event of an Outage**

<table>
<thead>
<tr>
<th>Daily</th>
<th>Every Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling System Coolant Level - Check</td>
<td>Air Starting Motor Lubricator Oil Level - Check</td>
</tr>
<tr>
<td>Electrical Connections - Check</td>
<td>Annunciator Panel - Inspect</td>
</tr>
<tr>
<td>Engine Oil Level - Check</td>
<td>Battery Charger - Check</td>
</tr>
<tr>
<td></td>
<td>Battery Electrolyte Level - Check</td>
</tr>
<tr>
<td></td>
<td>Engine Air Cleaner Service Indicator - Inspect</td>
</tr>
<tr>
<td></td>
<td>Engine Air Precleaner - Clean</td>
</tr>
<tr>
<td></td>
<td>Fuel Tank Water and Sediment - Drain</td>
</tr>
<tr>
<td></td>
<td>Generator - Inspect</td>
</tr>
<tr>
<td></td>
<td>Generator Bearing Temperature - Test/Record</td>
</tr>
<tr>
<td></td>
<td>Generator Load - Check</td>
</tr>
<tr>
<td></td>
<td>Jacket Water Heater - Check</td>
</tr>
<tr>
<td></td>
<td>Power Factor - Check</td>
</tr>
<tr>
<td></td>
<td>Space Heater - Test</td>
</tr>
<tr>
<td></td>
<td>Standby Generator Set Maintenance</td>
</tr>
<tr>
<td></td>
<td>Recommendations</td>
</tr>
</tbody>
</table>

*All of the following will affect the oil change interval: operating conditions, fuel type, oil type, and size of the oil sump. Scheduled oil sampling analyzes used oil in order to determine if the oil change interval is suitable for your specific engine.*

**Assume 2 weeks on generators, what is required maintenance?**

*Oil and coolant life is NOT linear.*

**What is YOUR plan to conduct maintenance during an extended outage?**

**Parts on hand?**
**Sampling available?**
**Redundancy?**

*SEBU8479-01: Standby MIS for 3516C Generator Set*
# Maintenance for Standby Gen Sets

## Diesel Generator Sets

<table>
<thead>
<tr>
<th>Maintenance Item</th>
<th>Hours *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil change</td>
<td>250-300</td>
</tr>
<tr>
<td>Top end</td>
<td>8-10k</td>
</tr>
<tr>
<td>Overhaul</td>
<td>18-20k</td>
</tr>
</tbody>
</table>

## Gas Generator Sets

<table>
<thead>
<tr>
<th>Maintenance Item</th>
<th>Hours *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil change</td>
<td>2000-4000</td>
</tr>
<tr>
<td>Spark plugs</td>
<td>2000-4000</td>
</tr>
<tr>
<td>Top end</td>
<td>20k</td>
</tr>
<tr>
<td>Inframe OH</td>
<td>40k</td>
</tr>
<tr>
<td>Major OH</td>
<td>80k</td>
</tr>
</tbody>
</table>

* Service intervals at B10 service life
Regular, Periodic, and Annual Maintenance

• What we typically think of as PM
• Document and trend data for future reference!
• Follow the manufacturer’s recommended maintenance interval schedule, especially for standby units.
• Follow predictive maintenance procedures for peaking units
Predictive Maintenance

• Monitor all aspects of engine operation
• Monitor wear trends
• Repair before failure
• Develop a long term strategy for engine and generator maintenance
• Having a good maintenance plan will reduce downtime
Repair Risk Management is Important to Control Costs

- Scheduled repairs per service manual intervals
- Predictive Repair Scheduling
  - Valve Recession, blow-by measurements, oil consumption, fuel consumption, exhaust emissions, etc.
  - Predictive repair scheduling can reduce service cost by up to 15%.
Estimated Maintenance Cost vs. Load Factor

Cost

Hours

Maintenance @ 100% Load Factor
Maintenance @ 85% Load Factor
Summary

- The demand for gas standby power is growing rapidly
  - Local codes require gas for standby
    - Contamination issues
  - Emissions regulations
    - Gas products can be lower cost than Tier 4 diesel
  - Natural gas infrastructure is robust
    - Secure in many natural disasters
  - Long run times
  - Parts & Service Support
  - Reliability

- Caterpillar is well positioned to assist
  - Product and product support
Questions?