Course Overview

- Background Information
- Theory and Operation
- Air/Fuel Delivery Systems
- Reciprocating Engine Emissions
- Emissions Control Methods
- Regulations
- Inspecting Stationary ICEs
NACT 271
Stationary Reciprocating Engines

Stationary RICE at a Glance

- 1.5 million stationary engines in U.S.
- 78% CI, 22% SI
- ~ 900,000 used for emergency power
- Sizes range from 1 kW – 10 MW
- Main HAP emitted: formaldehyde, acetaldehyde, acrolein, methanol, and PAH
- Main criteria pollutants emitted: NOx, CO, VOC, PM

Internal Combustion Generators by State 2006

April 10
Fuels

- Natural gas
- Gasoline
- Diesel
- Sewage gas
- Landfill gas
- Propane gas

History

- Gunpowder engines
- Steam engines
- Air engines
- Petroleum-fueled engines

Types of Reciprocating Engines

Spark-Ignition (S-I) or Otto Cycle

Compression-Ignition (C-I) or Diesel Cycle

Dual-Fuel (D-F)
Reciprocating Engine Operating Theory

Reciprocating Engine

- Valves
- Exhaust Manifold
- Air intake
- Cooling System
- Piston in Cylinder
- Intake Manifold
- Connecting Rod
- Crankshaft
- Flywheel
- Fuel Delivery System

Sizes

- Very small engines (1.0-3.0 in; 2-16 hp)
- Small bore (3.0-5.0 in; 3-50 hp)
- Medium bore (3.5-9.0 in; 50-1,200 hp)
- Large bore (8.0-18.0 in; 40-13,000 hp)
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Stationary Reciprocating Engines

8:1 Compression Ratio

Cylinder and Related Components

Four-Stroke-Cycle Spark-Ignition Engine
What is Power?

- Work = Distance x Force
  so...lifting a one pound weight one foot off the floor = one ft-lb of Work
- Power = Work/Time
  so...if it takes one minute to accomplish this, you have applied 1 ft-lb/min of Power
- One Horsepower = 33,000 ft-lb/min

Rating Engine Power

- Horsepower
- Brake Horsepower
- Rated Brake Horsepower
- Kilowatts
Ways to Determine Horsepower

\[ HP = \frac{\text{Mass flow rate of fuel (lb/hr or Btu/hr)}}{\text{Specific fuel consumption (lb/hp-hr or Btu/hp-hr)}} \]

\[ HP = \frac{\text{Torque (foot-lbs) x RPM}}{5252} \]

Comparison of S-I and C-I Engines

- **Air/Fuel:** C-I excess air only, S-I wide range of air/fuel
- **Compression:** C-I > S-I
- **Efficiency:** C-I > S-I
- **Durability:** C-I > S-I
- **Emissions:** C-I: NOx & PM, S-I: CO & NOx
Air/Fuel Delivery Systems

- Carburetor
- Gaseous Fuel Regulator
- Fuel Injection
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Stationary Reciprocating Engines

Modes of Fuel Injection

Gasoline Engine
Indirect FI
Spark Plug

Diesel Engine
Direct FI
Glow Plug

Gasoline Engine

Multiple Pump Injector

Diesel Engine

Unit Injector

Fuel Injectors

Multiple Pump Injector

Unit Injector

Nozzle Tip
Increasing Air Intake

- Turbochargers
- Superchargers
- Blower-Scavenging
Stationary Reciprocating Engines

Turbocharger

Intercooler

- Heat exchanger
- Cools air compressed by turbocharger or supercharger
- Used on most C-I engines

Emissions From SREs

Fuel (C, H, N, S) + Air (N\textsubscript{2}, O\textsubscript{2}) → H\textsubscript{2}O, CO\textsubscript{2}, CO, HC, NO\textsubscript{x}, SO\textsubscript{x}, Aldehydes, PM10
Stationary Reciprocating Engines

National Baseline HAP Emissions from RICE Units

<table>
<thead>
<tr>
<th>Type of Engine</th>
<th>Baseline HAP Emissions from All RICE Sources (tons/yr)</th>
<th>Baseline HAP Emissions from Major Sources (tons/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Engines:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2SLB Clean Gaseous Fuel</td>
<td>13,888</td>
<td>5,555</td>
</tr>
<tr>
<td>4SLB Clean Gaseous Fuel</td>
<td>11,729</td>
<td>4,692</td>
</tr>
<tr>
<td>4SRB Clean Gaseous Fuel</td>
<td>818</td>
<td>335</td>
</tr>
<tr>
<td>Compression Ignition</td>
<td>1,034</td>
<td>414</td>
</tr>
<tr>
<td>Subtotal</td>
<td>27,489</td>
<td>10,996</td>
</tr>
<tr>
<td>New Engines:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2SLB Clean Gaseous Fuel</td>
<td>1,565</td>
<td>626</td>
</tr>
<tr>
<td>4SLB Clean Gaseous Fuel</td>
<td>11,685</td>
<td>6,274</td>
</tr>
<tr>
<td>4SRB Clean Gaseous Fuel</td>
<td>785</td>
<td>314</td>
</tr>
<tr>
<td>Compression Ignition</td>
<td>1,165</td>
<td>466</td>
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<tr>
<td>Subtotal</td>
<td>19,200</td>
<td>7,680</td>
</tr>
<tr>
<td>Total</td>
<td>46,689</td>
<td>18,676</td>
</tr>
</tbody>
</table>

Time
Temperature
Turbulence
Oxygen
Stoichiometric Ratio

Relative amounts of air and fuel that when burned together, will result in complete combustion with no excess oxygen.

For Gasoline:

<table>
<thead>
<tr>
<th></th>
<th>AIR</th>
<th>FUEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASS</td>
<td>14.7</td>
<td>1</td>
</tr>
<tr>
<td>VOLUME</td>
<td>11,500</td>
<td>1</td>
</tr>
</tbody>
</table>

RICH = Less than 14.7:1
LEAN = Greater than 14.7:1

Exhaust Emissions and A/F (Natural Gas Engine)

<table>
<thead>
<tr>
<th>RPM Volume (at 15% O2)</th>
<th>NOx</th>
<th>CO</th>
<th>NMHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2000</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>14</td>
<td>1500</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>16</td>
<td>1000</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>18</td>
<td>500</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

Combustion Temp.

Power and A/F

<table>
<thead>
<tr>
<th>Air/Fuel Ratio</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Rich</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Lean</td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>
Stationary Reciprocating Engines

Generalized NOx vs. PM
(for '96 engines)

Mechanisms of Formation

- CO: Incomplete combustion
- NOx: High temperature combustion of N₂
- HC: Unburned or partially burned fuel
- SOx: Oxidation of sulfur
- PM₁₀: Partial combustion of engine oil
  Partially burned fuel

Factors Affecting Emissions

- Engine Design
- Fuel Type
- Atmospheric Conditions
- Operating Conditions
- Tuning and Maintenance
Emission Control Methods for Spark-Ignited Engines

- Alternate Fuels
- Positive Crankcase Ventilation
- Air/Fuel Ratio Adjustment
- Ignition Timing Retard
- Turbocharging or Supercharging with Intercooling
- Pre-Chamber/Lean-Burn
- Exhaust Gas Recirculation
- Pre-Stratified Charge
- Non-Selective Catalytic Reduction
- Selective Catalytic Reduction

Emission Control Methods for Compression-Ignited Engines

**NOx Control**

- Alternate Fuels
- Injection Timing Retard
- Modified Injectors
- Turbocharging or Supercharging with Intercooling
- Exhaust Gas Recirculation
- Lean-NOx Catalysts
- NOx Adsorbers ("Traps")
- Selective Catalytic Reduction

**PM Control**

- Alternate Fuels
- Modified Injectors
- Diesel Oxidation Catalyst
- Diesel Particulate Filters
- Fuel-Borne Catalyst
## Fuel Type

- Gaseous Fuels
- Diesel
- Liquid Fuels
- Alternate Fuels

## Reciprocating Engine Typical Emission Levels

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Lambda(*)</th>
<th>Mode</th>
<th>Emissions (g/bhp-hr)</th>
<th>NMHC</th>
<th>CO</th>
<th>NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>0.98 Rich</td>
<td>0.3</td>
<td>15.9</td>
<td>8.3</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.99 Rich</td>
<td>0.2</td>
<td>8.0</td>
<td>11.0</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.06 Lean</td>
<td>1.0</td>
<td>1.0</td>
<td>18.0</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.74 Lean</td>
<td>1.0</td>
<td>3.0</td>
<td>0.7</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>1.6-2.2 Lean</td>
<td>0.3</td>
<td>1.0</td>
<td>11.6</td>
<td>0.25-0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual Fuel</td>
<td>1.6-1.9 Lean</td>
<td>0.5</td>
<td>2.5</td>
<td>4.1</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*From: Emission Control Technology for Stationary Internal Combustion Engines, MECA, July 1997, p. 3*

## Percentages of Gases in Gaseous Fuels

<table>
<thead>
<tr>
<th>Type of Gaseous Fuel</th>
<th>Type of Gaseous Fuel</th>
<th>Methane</th>
<th>Ethane</th>
<th>Propane</th>
<th>Butane+</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>% in Fuel</td>
<td>Natural</td>
<td>95%</td>
<td>4%</td>
<td>1%</td>
<td>1%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Propane</td>
<td>65%</td>
<td>95%</td>
<td>95%</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digester</td>
<td>55%</td>
<td>4%</td>
<td>1%</td>
<td>1%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Landfill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45%</td>
</tr>
</tbody>
</table>

*Courtesy Waukesha*
Positive Crankcase Ventilation (PCV) System

- Some exhaust gases escape past pistons into crankcase of engine
- Crankcase gases used to be vented to atmosphere
- These gases now recirculated to intake manifold through a hose

Air Fuel Ratio Adjustment:

**Rich Adjustment**
- Decrease NOx by decrease O2
- + cooling by excess fuel
- Increase HC, CO
- May increase fuel consumption

**Lean Adjustment**
- Decrease NOx by decrease temp
- Increase fuel efficiency at mod. lean operation
- HC, CO, fuel consumption may increase at extremely lean

Piston at Bottom Dead Center

Piston at 5° Before Top Dead Center

Piston at ~15° Before Top Dead Center

Piston at ~15° Before Top Dead Center Timing Retarded 10°

Piston at Top Dead Center
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**NOx Reductions vs. Ignition Retard for Lean Burn Engines**

![Diagram showing NOx reductions vs. ignition retard](image)

**Effects of Air/Fuel Ratio on NOx Reductions at Two Ignition Timing Retard Settings**

![Diagram showing effects of air/fuel ratio on NOx reductions](image)

**Timing Retard**

- NOx control by lowering combustion temperature
- Indicated by degrees of crankshaft rotation
- Injection TR for C-I / Ignition TR for S-I

**Advantages**
- Low capital, operating costs
- Easy to adjust
- Minimal increase CO, HC

**Disadvantages**
- Reduce max power output
- Reduce fuel efficiency
- May increase PM (smoke) in C-I
- May increase exhaust temps
Turbocharger with Intercooler

Low-Emission Combustion or "CleanBurn®" Engine

Open Chamber Prechamber

Pre-Chamber System

Spark plug Prechamber Fuel Injector

Courtesy Waukesha
Pre-Stratified Charge: Key Points

- 4-stoke, carbureted engines
- Constant load best
- Operated by manifold vacuum
- NOx reductions to 2 g/bhp-hr

Catalytic Converters

\[
\begin{align*}
\text{CO} & \rightarrow \text{CO}_2 \\
\text{HC} & \rightarrow \text{H}_2\text{O} \\
\text{NO}_x & \rightarrow \text{N}_2 \\
\text{CO} + \text{HC} + \text{NO}_x & \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 \\
\end{align*}
\]

- Oxidation Catalyst (Pt, Pd)
- Reduction Catalyst (Rh)
- Three-Way or Non-Selective Catalyst
Non-Selective Catalytic Reduction (NSCR)

- Converts NOx, CO, HCs $\rightarrow$ N₂, CO₂, H₂O
- Rich-burn engines only
- Natural gas applications mainly
- A/F must be precisely controlled $\rightarrow$ O₂ sensor
- Catalyst temperature 800°F - 1200°F
Lean NOx Catalyst

- Diesel fuel injected into exhaust as reducing agent for NOx
- Zeolite substrate stores and releases HCs
- Platinum low-temperature catalyst (200 - 300 °C)
- Copper high-temperature catalyst (350 - 500+ °C)
- ~ 30% NOx conversion
- ~ 3% fuel economy penalty
- Sulfur in fuel decreases efficiency, increases PM
NOx Adsorbers ("Traps")

- NO catalytically oxidized to NO₂
- NO₂ stored in alkaline earth oxide as nitrate
- Stored NOx removed in two-step reduction process:
  - Temporary fuel-rich exhaust to release
  - NOx converted to N₂ over precious metal catalyst
- Engine management system needed
- 50 - 90% efficiency
- Sulfur poisoning

SCR System

![SCR System diagram](image)

**NOx in ENGINE EXHAUST**

**CATALYST**

**AMMONIA (NH₃)**

**AMMONIA FEEDER**

**CONTROL VALVE**

**N₂ + H₂O (+ NH₃)**

**EMISSIONS**

Major Parts of SCR System

![Major Parts of SCR System diagram](image)

- Stack
- CEM
- SCR Reactor
- SCR Catalyst
- Ammonia Tank
- Temperature Control
- Ammonia Control
- Ammonia Booster
- Engine
- Generator
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SCR Catalyst

Catalyst Module
Stationary Reciprocating Engines

% NOx Removed vs. Vanadium Pentoxide Catalyst Temperature

Most effective operating range

Figure 304.8
Selective Catalytic Reduction (SCR)

- NOx Control thru Ammonia Injection
- Lean-Burn, Diesel, and Gas Turbines
- Metal-based ($V_2O_5$, $TiO_2$, $WO_3$, $Al_2O_3$) or Zeolites
- 70 - 90+% control of NOx

SCR Pros and Cons

- Advantages
  - works better than TWC with excess oxygen
  - cheaper than reduction catalyst using noble metal (for large-scale applications)

- Disadvantages
  - most expensive NOx control method
  - high maintenance
  - ammonia slip
  - increased fuel consumption.

Diesel Oxidation Catalyst (DOC)
Diesel Particulate Filter (DPF)

- Collection of PM on filter with exhaust gas flow-through
- Regeneration required
  - High exhaust temperature (600 - 650 °C)
  - Catalytic oxidation of particulate (~375 °C)
  - Oxidize NO to NO2 \( \rightarrow \) adsorbs \( \rightarrow \) reduces regeneration temperature
  - Fuel-borne catalyst
  - Ceramic coatings
  - Engine adjustments
Regulations Affecting Stationary Engines

RICE NESHAP
- Applies to existing, new, and reconstructed stationary engines (both CI and SI)
- Focus is air toxics (HAP)
- Established under CAA section 112

CI/SI ICE NSPS
- Applies to new, modified, and reconstructed stationary CI/SI engines
- Focus is criteria pollutants
- Established under CAA section 111

Definitions

"Stationary Internal Combustion Engine":
Any internal combustion engine, except combustion turbines, that converts heat energy into mechanical work and is not mobile. A stationary ICE is not a nonroad engine as defined at 40 CFR 1068.30, and is not used to propel a motor vehicle or a vehicle used solely for competition. Stationary ICE includes reciprocating ICE, rotary ICE, and other ICE except combustion turbines.

NON ROAD ENGINE
- ...it is in or on a piece of equipment that is self-propelled or serves a dual purpose by both propelling itself and performing another function
- ...it is in or on a piece of equipment that is intended to be propelled while performing its 40 CFR 1068.30 function
- ...by itself or in or on a piece of equipment, is portable or transportable, meaning designed to be and capable of being carried or moved from one location to another.
Definitions (con’t)

Rich burn engine - Any four-stroke spark ignited engine where the manufacturer’s recommended operating air/fuel ratio divided by the stoichiometric air/fuel ratio at full load conditions is less than or equal to 1.1.

Engines originally manufactured as rich burn engines, but modified prior to December 19, 2002 with passive emission control technology for NOX (such as pre-combustion chambers) will be considered lean burn engines. Also, existing engines where there are no manufacturer’s recommendations regarding air/fuel ratio will be considered a rich burn engine if the excess oxygen content of the exhaust at full load conditions is less than or equal to 2 percent.

Lean burn engine – Any two-stroke or four-stroke spark ignited engine that does not meet the definition of a rich burn engine.

Timeline of Final Regulations

<table>
<thead>
<tr>
<th>Date</th>
<th>Rule</th>
<th>Type of engines covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 2004</td>
<td>NESHAP</td>
<td>Existing/new engines &gt;500 HP at major sources</td>
</tr>
<tr>
<td>June 2006</td>
<td>NSPS</td>
<td>New CI engines</td>
</tr>
<tr>
<td>January 2008</td>
<td>NSPS</td>
<td>New SI engines</td>
</tr>
<tr>
<td>March 2010</td>
<td>NESHAP</td>
<td>New engines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;500 HP at major sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;500 HP at area sources</td>
</tr>
<tr>
<td>August 2010</td>
<td>NESHAP</td>
<td>Existing CI engines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;500 HP at major sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;500 HP at area sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-emergency CI &gt;500 HP at major sources</td>
</tr>
<tr>
<td>June 2011</td>
<td>NSPS</td>
<td>Amendments for CI and SI engines</td>
</tr>
<tr>
<td>January 2013</td>
<td>NSPS</td>
<td>Amendments to NSPS for CI and SI engines</td>
</tr>
</tbody>
</table>

Applicability

**RICE NESHAP**
- Applies to stationary CI and SI engines, both existing and new

**CI ICE NSPS**
- Applies to stationary CI engines:
  - Ordered after July 11, 2005 and manufactured after April 1, 2008
  - Modified or reconstructed after July 11, 2005

**SI ICE NSPS**
- Applies to stationary SI engines:
  - Ordered after June 12, 2006 and manufactured on or after
    - July 1, 2006 if >500 HP (except lean burn 500–1,350)
    - January 1, 2008 if lean burn 500–1,350
    - July 1, 2006 if <500 HP
    - January 1, 2008 if emergency >25 HP
  - Modified or reconstructed after June 12, 2006

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## Modification and Reconstruction

- **Modification** (NSPS only)
  - Physical or operational change to an existing facility which results in an increase in the emission rate to the atmosphere of a regulated pollutant
  - See 40 CFR 60.14

- **Reconstruction**
  - Replacement of components of an existing facility to such an extent that the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable entirely new facility, and it is technologically and economically feasible to meet the applicable standards
  - See 40 CFR 60.15 and 63.2

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## Stationary RICE NESHAP

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## RICE NESHAP Background

- Regulates HAP emissions from stationary RICE at both major and area sources of HAP
  - **Major**: ≥10 tons/year single HAP or ≥25 tons/year total HAP
  - **Area**: not major
- All sizes of engines are covered
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Stationary Reciprocating Engines

General Subcategorization Approach

Existing vs. New

Construction commenced before:

- >500 HP at major source
  - Existing: December 19, 2002
  - New

- ≤500 HP at major source and all HP at area source
  - Existing: June 12, 2006
  - New

Determining construction date: owner/operator has entered into a contractual obligation to undertake and complete, within a reasonable amount of time, a continuous program for the on-site installation of the engine.

- Does not include moving an engine to a new location.

RICE NESHAP Applicability

- ONLY STATIONARY ENGINES NOT SUBJECT: existing emergency engines located at residential, institutional, or commercial area sources used or obligated to be available ≤15 hr/yr for emergency demand response or voltage/frequency deviation, and not used for local reliability

- residential: includes homes, apartment buildings
- commercial: includes office buildings, hotels, stores, telecommunications facilities, restaurants, financial institutions, doctor’s offices, sports and performing arts facilities
- institutional: includes medical centers, nursing homes, research centers, institutions of higher education, correctional facilities, elementary and secondary schools, libraries, religious establishments, police stations, fire stations


April 10
### Emission Standards: Existing RICE at Major Sources

<table>
<thead>
<tr>
<th>HP</th>
<th>Engine Subcategory</th>
<th>Non-emergency</th>
<th>Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>SI 25LB</td>
<td>SI 45LB</td>
<td>SI 45RB</td>
</tr>
<tr>
<td>&lt;100</td>
<td>Change oil and filter and inspect air cleaner (CI) or spark plugs (SI) every 1,000 hours of operation or annually; inspect hoses and belts every 500 hours of operation or annually</td>
<td>230 ppm CO</td>
<td>225 ppm CO</td>
</tr>
<tr>
<td>100-300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300-500</td>
<td>Change oil and filter and inspect air cleaner (CI) or spark plugs (SI) every 500 hours of operation or annually; inspect hoses and belts every 500 hours of operation or annually</td>
<td>49 ppm CO or 70% CO reduction</td>
<td>47 ppm CO</td>
</tr>
<tr>
<td>&gt;500</td>
<td>No standards</td>
<td>No standards</td>
<td>No standards</td>
</tr>
</tbody>
</table>

Note: Existing limited use engines <500 HP at major sources do not have to meet any emission standards. Existing limited use engines >500 HP at major sources must meet the pre-2001 standards.

### Emission Standards – New RICE at Major Sources

<table>
<thead>
<tr>
<th>HP</th>
<th>Engine Subcategory</th>
<th>Non-emergency</th>
<th>Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>SI 25LB</td>
<td>SI 45LB</td>
<td>SI 45RB</td>
</tr>
<tr>
<td>&lt;250</td>
<td>Comply with CI NSPS</td>
<td>Comply with SI NSPS</td>
<td>Comply with SI NSPS</td>
</tr>
<tr>
<td>250-500</td>
<td></td>
<td>14 ppm CH₄</td>
<td>350 gph CH₄ or 74% CO reduction</td>
</tr>
<tr>
<td>&gt;500</td>
<td>350 gph CH₄ or 74% CO reduction</td>
<td>350 gph CH₄ or 74% CO reduction</td>
<td>No standards</td>
</tr>
</tbody>
</table>

Note: New limited use engines >500 HP at major sources do not have to meet any emission standards under the NACT.

### Compliance Requirements: RICE at Major Sources

<table>
<thead>
<tr>
<th>Engine Subcategory</th>
<th>Compliance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing non-emergency:</td>
<td>• Initial emission performance test</td>
</tr>
<tr>
<td>&gt;100-500 HP at major source</td>
<td>• Subsequent performance testing every 5,760 hours of operation or 3 years for engines &gt;500 HP (5 years if limited use)</td>
</tr>
<tr>
<td>&gt;500 HP at major source</td>
<td>• Operating limitations - catalytic pressure drop and inlet temperature for engines &gt;500 HP</td>
</tr>
<tr>
<td></td>
<td>• Notifications</td>
</tr>
<tr>
<td></td>
<td>• Semiannual compliance reports (annual if limited use)</td>
</tr>
<tr>
<td></td>
<td>Existing non-emergency CI &gt;300 HP:</td>
</tr>
<tr>
<td></td>
<td>• Ultra low sulfur diesel (ULSD)</td>
</tr>
<tr>
<td></td>
<td>• Crankcase emission control requirements</td>
</tr>
</tbody>
</table>
### Compliance Requirements: RICE at Major Sources

<table>
<thead>
<tr>
<th>Engine Subcategory</th>
<th>Compliance Requirements</th>
</tr>
</thead>
</table>
| **Existing non-emergency:** | - Initial emission performance test  
- Subsequent performance testing semiannually (can reduce frequency to annually)*  
- Operating limitations - catalyst pressure drop and inlet temperature  
- Notifications  
- Semiannual compliance reports |
| **New non-emergency:** | - Initial notification  
- Reporting and USD for emergency engines used for emergency demand response  
- Monitor/record fuel usage daily  
- Annual report of fuel usage |
| **New emergency/limited use > 500 HP at major source** | - Initial notification  
- Monitor/record fuel usage daily  
- Annual report of fuel usage |
| **New non-emergency LFG/DG > 500 HP at major source** | - Initial notification  
- Monitor/record fuel usage daily  
- Annual report of fuel usage |

*Subsequent testing required for 458B engine complying with formaldehyde % reduction standard only if engine is ≤500 HP

### Emission Standards: Existing Non-Emergency RICE at Area Sources

<table>
<thead>
<tr>
<th>HP</th>
<th>Engine Subcategory</th>
<th>Non-emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SI 25LB</td>
<td>SI 45 in remote areas</td>
</tr>
<tr>
<td>≤500</td>
<td>Change oil/Filter &amp; inspect air cleaner every 1,000 hours or annually, inspect hours/belts every 4,320 hours or annually</td>
<td>Change oil/Filter, inspect spark plugs, &amp; inspect hours/belts every 4,320 hours or annually</td>
</tr>
</tbody>
</table>
| 500-500 | 49 ppm CO or 10\% CO2 reduction | Change oil/Filter, inspect spark plugs, & inspect hours/belts every 2,360 hours of operation or annually | If engine used < 24 hours:  
- L2LB: Install oxidation catalyst  
- 44LB: Install NSCR |
| >500 | \[25\% \text{ CO or 10\% CO2 reduction} \] | \[25\% \text{ CO or 10\% CO2 reduction} \] | \[25\% \text{ CO or 10\% CO2 reduction} \] | \[25\% \text{ CO or 10\% CO2 reduction} \] |

New Non-Emergency RICE located at Area Sources: meet Stationary Engine NSPS
- *part 60 subpart III (C) or part 60 subpart IJJ (SI)
# Compliance Requirements: Non-Emergency Engines at Area Sources

<table>
<thead>
<tr>
<th>Engine Subcategory</th>
<th>Compliance Requirements</th>
</tr>
</thead>
</table>
| Existing non-emergency CI >300 HP at area source | Initial emission performance test  
  (Subsequent performance testing every 8,760 hours of operation or 3 years for engines >500 HP  
  (5 years if limited use))  
  (Operating limitations - catalyst pressure drop and  
  inlet temperature for engines >500 HP)  
  Notifications  
  Semiannual compliance reports (annual if limited use)  
  Ultra low sulfur diesel (ULSD)  
  Crankcase emission control requirements |
| Existing non-emergency SI  
  45LB/45RB >500 HP at area source used ≤24 hours/year and not in remote area | Initial and annual catalyst activity checks  
  High temperature engine shutdown or  
  continuously monitor catalyst inlet temperature  
  Notifications  
  Semiannual compliance reports |

## How is “Remote” Defined?

- Remote defined as:
  - Located in offshore area; or
  - Located on a pipeline segment with 10 or fewer buildings intended for human occupancy and no buildings with 4 or more stories within 220 yards on either side of a continuous 1-mile length of pipeline (DOT Class 1 area), and the pipeline segment is not within 100 yards of a building or small well-defined outside area (playground, etc.) occupied by 20 or more persons on at least 5 days a week for 10 weeks in any 12-month period; or
  - Not located on a pipeline and having 5 or fewer buildings intended for human occupancy and no buildings with 4 or more stories within a 0.25 mile radius around the engine

- Engine must meet remote definition as of October 19, 2013
Emergency Engine Operational Limitations

- Unlimited use for emergencies (e.g., power outage, fire, flood)
- 100 hr/yr for:
  - maintenance/testing
  - emergency demand response (EDR) when Energy Emergency Alert Level 2 has been declared by Reliability Coordinator
  - voltage or frequency deviates by 5% or more below standard
- 50 hr/yr of the 100 hr/yr allocation can be used for:
  - non-emergency situations if no financial arrangement
  - local reliability as part of a financial arrangement with another entity if:
    - existing RICE at area source
    - engine is dispatched by local transmission/distribution system operator
    - dispatch intended to mitigate local transmission and/or distribution limitations so as to avert potential voltage collapse or line overloads
    - dispatch follows reliability, emergency operation, or similar protocols that follow specific NERC, regional, state, public utility commission, or local standards or guidelines
    - power provided only to facility or to support local distribution system
    - owner/operator identifies and records dispatch and standard that is being followed
  - peak shaving in local system operator program until May 3, 2014 if existing RICE at area source

Compliance Requirements: Emergency Engines at Area Sources

Existing engine:
- Change oil/filter & inspect hoses/belts every 500 hours or annually; inspect air cleaner (C1) or spark plugs (SI) every 1,000 hours or annually
- May use oil analysis program
- Operate/maintain per manufacturer’s instructions or owner-developed maintenance plan
- Minimize startup/idle
- Non-resettable hour meter
- Records of hours of operation and maintenance
- Initial notifications NOT required

New engine:
- Meet Stationary Engine NSPS
  - part 60 subpart III if C1, part 60 subpart JJJJ if SI

Oil Analysis Programs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condensing Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Base Number (C RICE only)</td>
<td>&lt;30% of the TBN of the oil when new</td>
</tr>
<tr>
<td>Total Acid Number (SI RICE only)</td>
<td>Increases by more than 3.0 mg of potassium hydroxide per gram from TBN of the oil when new</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Changed by more than 20% from the viscosity of the oil when new</td>
</tr>
<tr>
<td>% Water Content by volume</td>
<td>&gt;0.5</td>
</tr>
</tbody>
</table>

Oil analysis must be performed at same frequency specified for oil changes
- If condemned, change oil within 2 business days
  - Owner/operator must keep records of the analysis
Reporting Requirements for Emergency Engines

Requirements apply to emergency RICE >100 HP that are:
- Operated or contractually obligated to be available >15 hr/yr (up to 100 hr/yr) for emergency demand response or voltage/frequency deviation, or
- Operated for local reliability (up to 50 hr/yr)
- Beginning with 2015 operation, report electronically by March 31 of following year:
  - Facility name/address
  - Engine rating, model year, lat/long
  - Date, start time, end time for operation for purposes above
  - Number of hours engine is contractually obligated for emergency demand response or voltage/frequency deviation
  - Entity that dispatched engine for local reliability and situation that necessitated dispatch
  - Deviations from fuel requirement

Submit report electronically through the Compliance and Emissions Data Reporting Interface
- Accessed through EPA's Central Data Exchange at http://www.epa.gov/cdx

Fuel Requirements for Emergency Engines

Requirements apply to emergency CI RICE >100 HP and displacement <30 liters/cylinder that are:
- Operated or contractually obligated to be available >15 hr/yr (up to 100 hr/yr) for emergency demand response or voltage/frequency deviation, or
- Operated for local reliability (up to 50 hr/yr)
- Beginning January 1, 2015, use ultra low sulfur diesel fuel
  - Existing inventory may be depleted

Key Dates

Initial applicability notifications for engines subject to notification requirements were due by:
- August 31, 2010 for existing CI RICE
- February 16, 2011 for existing SI RICE

Compliance dates:
- June 15, 2007
  - Existing RICE ≥500 HP at major sources (except non-emergency CI ≥500 HP at major sources)
- May 3, 2013
  - Existing CI RICE (except emergency CI ≥500 HP at major sources)
- October 19, 2013
  - Existing SI RICE ≤500 HP at major sources and all HP at area sources
  - Upon startup for new engines
Compliance Extension [§63.6(i)]

- Under 40 CFR 63.6(i), EPA can grant up to 1 year if necessary to install controls
- State can also approve if
  - Delegated the NESHAP, or
  - The source is required to obtain a Title V operating permit, and state has an approved permit program
- Application process
  - Submit written request to EPA regional office or state 120 days in advance of the compliance date (unless the need arose later due to circumstances beyond reasonable control)
  - Include a schedule for construction and final compliance and description of the controls

Stationary ICE NSPS

Stationary CI Engine NSPS

- 40 CFR part 60 subpart IIII
- Affects new, modified, and reconstructed stationary CI engines
- Originally promulgated July 11, 2006
- Amended June 28, 2011
CI ICE NSPS Applicability

- CI Engines:
  - constructed (ordered) after July 11, 2005 and manufactured after April 1, 2006 (July 1, 2006 for fire pump engines)
  - modified/reconstructed after July 11, 2005

Note: engine manufacturers must certify 2007 model year and later stationary CI engines <30 liters/cylinder displacement

Emission Standards

- <30 liters/cylinder
  - Meet Tier standards equivalent to standards for nonroad engines

- ≥30 liters/cylinder
  - NOx limits (g/kW-hr): equivalent to EPA standards for large marine engines
  - PM limit:
    - 60% reduction or 0.15 g/kW-hr for non-emergency
    - 0.40 g/kW-hr for emergency

Fuel Requirements

<table>
<thead>
<tr>
<th>Date</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 1, 2007</td>
<td>Low sulfur diesel (LSD)</td>
</tr>
<tr>
<td>October 1, 2010</td>
<td>Ultra low sulfur diesel (ULSD)</td>
</tr>
<tr>
<td>Engines &lt;30 liters/cylinder displacement</td>
<td>Max sulfur content 15 ppm</td>
</tr>
<tr>
<td></td>
<td>Minimum cetane index of 40 or max aromatic content of 35 volume %</td>
</tr>
<tr>
<td>June 1, 2012</td>
<td>1,000 ppm sulfur diesel</td>
</tr>
</tbody>
</table>
Engine Manufacturer Compliance Requirements

- Engine manufacturers must certify 2007 model year and later engines with a displacement <30 liters/cylinder
  - Certification = EPA Certificate of Conformity

Owner/Operator Compliance Requirements

- 2007 model year and later with displacement <30 liters/cylinder*
  - Purchase certified engine
  - Install, configure, operate and maintain engine per manufacturer's instructions or manufacturer-approved procedures
    - Owner/operator performance testing not required
  - Displacement ≥30 liters/cylinder
    - Initial performance test
    - Annual performance test for non-emergency engine
    - Continuously monitor operating parameters

*For CI fire pump engines, 2006-2011 model year and later (depending on engine size)
Stationary Reciprocating Engines

Monitoring/Recordkeeping/Reporting

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Engines</td>
<td>Non-resettable hour meter and records of operation if engine does not meet non-emergency engine standards</td>
</tr>
<tr>
<td>Equipped with diesel particulate filter (DPF)</td>
<td>Backpressure monitor and records of corrective actions</td>
</tr>
<tr>
<td>Non-emergency &gt;3,000 HP or with displacement &gt;10 liters/cylinder and Pre-2007 model year &gt;175 HP that are not certified</td>
<td>Submit initial notification • Keep records of notifications and engine maintenance • If certified, keep records of documentation of engine certification • If not certified, keep records of compliance demonstrations</td>
</tr>
</tbody>
</table>

Stationary SI Engine NSPS

- 40 CFR part 60 subpart JJJJ
- Affects new, modified, and reconstructed stationary SI engines
- Initially promulgated on January 18, 2008
- Amended June 28, 2011

SI ICE NSPS Applicability

- SI engines constructed (ordered) after June 12, 2006 and
  - Manufactured On/After: Engine Type
    - July 1, 2007: ≥500 HP (except lean burn 500≤HP<1,350)
    - January 1, 2008: Lean burn 500≤HP<1,350
    - July 1, 2008: ≤500 HP
    - January 1, 2009: Emergency >25 HP
- Modified/reconstructed after June 12, 2006

Note: engine manufacturers must certify stationary SI engines ≤25 HP and engines >25 HP that are gasoline or rich burn LPG
Emission Standards

- Phased in over time with increasing levels of stringency
- Output-based, units of g/KW-hr (g/HP-hr)
- ppmvd@15% O₂ standards for some engines
- Pollutants: NOₓ, CO, VOC
- Some standards modeled after EPA’s standards for nonroad SI engines

Emission Standards (In General)

<table>
<thead>
<tr>
<th>Engine</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤25 HP (all engines)</td>
<td>Part 90 or part 1054 standards for new nonroad SI engines</td>
</tr>
<tr>
<td>Non-emergency gasoline and rich burn LPG</td>
<td>Part 1048 standards for new nonroad SI engines</td>
</tr>
<tr>
<td>Non-emergency natural gas and lean burn LPG 25&lt;HP&lt;100</td>
<td>Part 1048 standards for new nonroad SI engines (or other options)</td>
</tr>
<tr>
<td>≤100 HP and not gasoline or rich burn LPG</td>
<td>Standards in Table 1 of subpart JJJJ, part 1048 standards for some engines</td>
</tr>
</tbody>
</table>

Owners/operators of gasoline engines must use gasoline that meets the sulfur limit in 40 CFR 80.115 – cap of 80 ppm

Compliance Requirements for Owners/Operators

- **Certified engines**
  - Install, configure, operate and maintain engine according to manufacturer’s instructions
  - If you do not operate/maintain according to manufacturer’s instructions:
    - keep maintenance plan and maintenance records
    - operate consistent with good air pollution control practices
    - 1000≤HP<500 – initial performance test
    - >500 HP - initial performance test and subsequent every 8,760 hours or 3 years, whichever is first
Compliance Requirements for Owners/Operators

- **Non-certified engines:**
  - Maintenance plan
  - Performance testing
    - 25+HP diesel - initial test
    - >500 HP - initial test and subsequent every 8-760 hours or 3 years, whichever is first
    - Conduct within 10% of peak (or highest achievable) load

- **Monitoring/recordkeeping/reporting includes:**
  - Non-resettable hour meter and records of operation for emergency engines
  - Documentation of certification
  - Records of engine maintenance
  - Initial notification for non-certified engines >500 HP
  - Results of performance testing within 60 days of test

### EPA Region, Geographic Area, Contact, Phone, Email

<table>
<thead>
<tr>
<th>Region</th>
<th>Geographic Area</th>
<th>Contact</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CT, MA, ME, NH, RI, VT</td>
<td>Susan Lanyon</td>
<td>(401) 513-1556</td>
<td><a href="mailto:lanyon.susan@epa.gov">lanyon.susan@epa.gov</a></td>
</tr>
<tr>
<td>II</td>
<td>NJ, NY, PA, VI</td>
<td>Ray Crystal</td>
<td>(617) 518-1745</td>
<td><a href="mailto:crystalray@epa.gov">crystalray@epa.gov</a></td>
</tr>
<tr>
<td>III</td>
<td>DE, MD, PA, VA, WV, DC</td>
<td>Umesh Dholakia</td>
<td>(215) 637-4023</td>
<td><a href="mailto:dholakia.umesh@epa.gov">dholakia.umesh@epa.gov</a></td>
</tr>
<tr>
<td>IV</td>
<td>FL, NC, SC, KY, TN, GA, AL, MS</td>
<td>Ray Chalmers</td>
<td>(701) 814-2746</td>
<td><a href="mailto:chalmers.ray@epa.gov">chalmers.ray@epa.gov</a></td>
</tr>
<tr>
<td>V</td>
<td>IL, IN, WI, MO, MN</td>
<td>Sue Trine</td>
<td>(312) 753-9228</td>
<td><a href="mailto:trine.sue@epa.gov">trine.sue@epa.gov</a></td>
</tr>
<tr>
<td>VI</td>
<td>WI, Illinois</td>
<td>Nathan Frank</td>
<td>(312) 886-3650</td>
<td><a href="mailto:frank.nathan@epa.gov">frank.nathan@epa.gov</a></td>
</tr>
<tr>
<td>VII</td>
<td>IA, KS, MO, NE</td>
<td>Sara Brenman</td>
<td>(312) 886-5043</td>
<td><a href="mailto:brenman.sara@epa.gov">brenman.sara@epa.gov</a></td>
</tr>
<tr>
<td>VIII</td>
<td>OH, MN</td>
<td>William MacDowell</td>
<td>(312) 886-4798</td>
<td><a href="mailto:macdowell.william@epa.gov">macdowell.william@epa.gov</a></td>
</tr>
<tr>
<td>IX</td>
<td>AR, LA, NM, OK, TX</td>
<td>Donald M. Smith</td>
<td>(214) 665-7710</td>
<td><a href="mailto:smith.donald@epa.gov">smith.donald@epa.gov</a></td>
</tr>
<tr>
<td>X</td>
<td>AK, ID, WA, OR</td>
<td>Heather Valdez</td>
<td>(206) 553-4220</td>
<td><a href="mailto:valdez.heather@epa.gov">valdez.heather@epa.gov</a></td>
</tr>
</tbody>
</table>

### Inspection Procedures
NACT 271
Stationary Reciprocating Engines

Pre-Inspection
1. Obtain/set up inspection report form
2. File Review
3. Regulation Review
4. Equipment Check
5. Pre-Entry and Entry
6. Pre-Inspection Meeting
7. Permit Check

Typical Permit Conditions
• Fuels
• Hours of operation
• Emission limits
• Emission control equipment
• Recordkeeping
• CEMs

Inspection
• Visible Emissions Evaluation
• General Upkeep and Maintenance
• Monitoring Instruments (operation, records)
• Fuel Type, Quality (records, samples)
• Control Devices
• Maintenance Records
Stationary Reciprocating Engines

Inspection (con’t.)

• Emissions Screening
• Source Test
• Timing Check
• Derating Verification
NACT 271
Stationary Reciprocating Engines

FURTHER INFORMATION

- www3.epa.gov/ttn/atw/iceengines/ - In addition to regulatory information, go to Implementation info and Regulatory Navigation Interactive Tools
- www3.epa.gov/region 1/rice/
- www.combustionportal.org