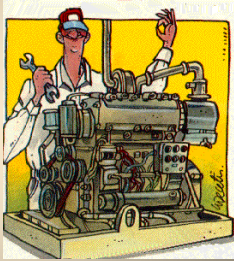



NACT 271

Stationary Reciprocating Engines

Stationary Reciprocating Engines

NACT 271



Short pre quiz

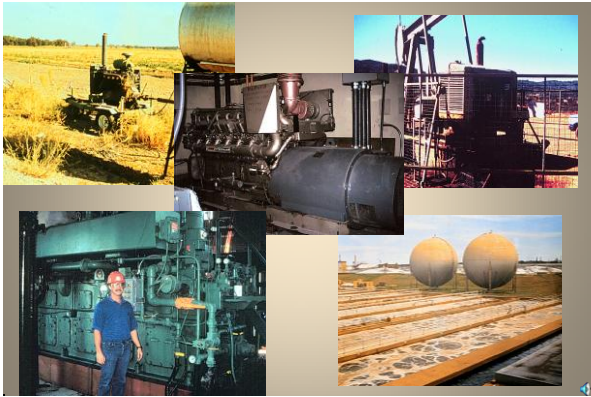
1. 4 stroke	11. Engine Displacement
2. CI	12. Scavenging
3. Fuel Injection	13. Reed valves
4. 2SSI	14. ICE vs RICE
5. NSC	15. Otto cycle
6. Lean burn	16. Oxy Cat
7. Reduction reaction	17. Diesel trap
8. Stroke	18. HAPs
9. Combustion Chamber	19. Intercooler
10. Torque	20. Turbocharger

Course Overview

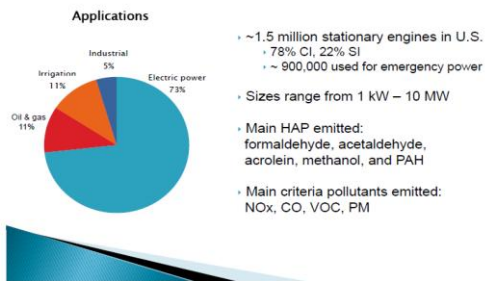
- Background Information
- Theory and Operation
- Air/Fuel Delivery Systems
- Reciprocating Engine Emissions
- Emissions Control Methods
- Regulations
- Inspecting Stationary ICEs

NACT 271

Stationary Reciprocating Engines



Stationary RICE at a Glance



Internal Combustion Generators by State 2006

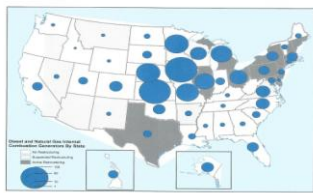


Figure 3-2. Internal Combustion Generators by State: 2006
 Source: U.S. Department of Energy, Energy Information Administration, 2007 "2006 EIA-906/908 Monthly Time Series."

NACT 271

Stationary Reciprocating Engines

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

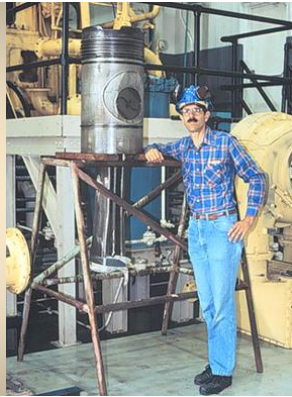
Compression-Ignition (C-I) or Diesel Cycle

Dual-Fuel (D-F)

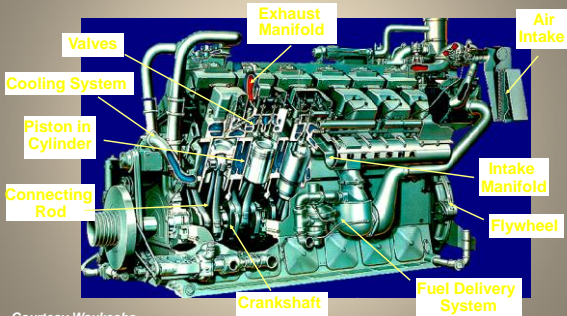
NACT 271

Stationary Reciprocating Engines

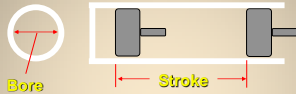
Reciprocating Engine Operating Theory



Reciprocating Engine



Sizes

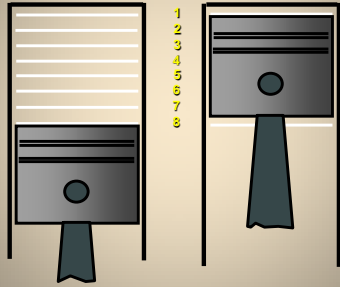


- Very small engines (1.0-3.0 in; 2-16 hp)
- Small bore (3.0-5.0 in; 3-50 hp)
- Medium bore (3.5-9.0 in; 50-1,200 hp)
- Large bore (8.0-18.0 in; 40-13,000 hp)

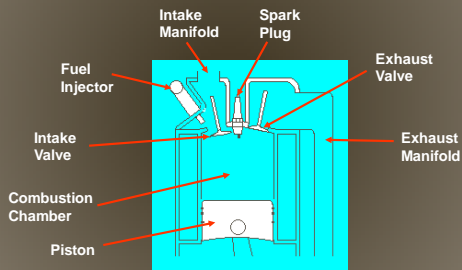
NACT 271

Stationary Reciprocating Engines

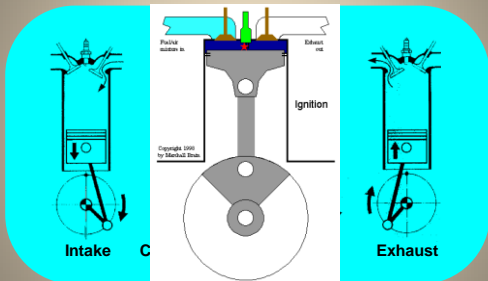
8:1 Compression Ratio



Cylinder and Related Components

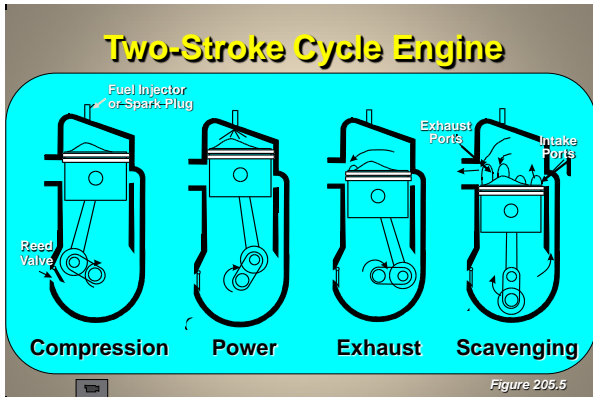


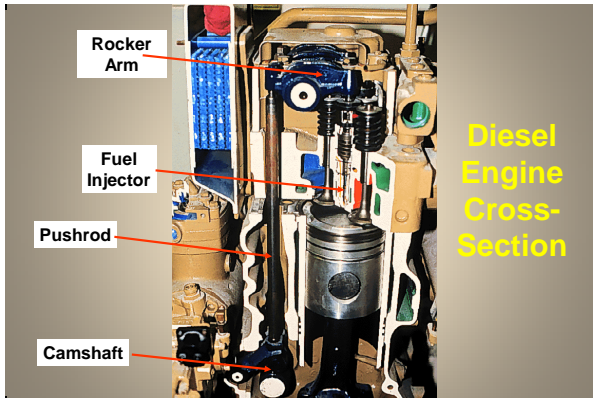
Four-Stroke-Cycle Spark-Ignition Engine

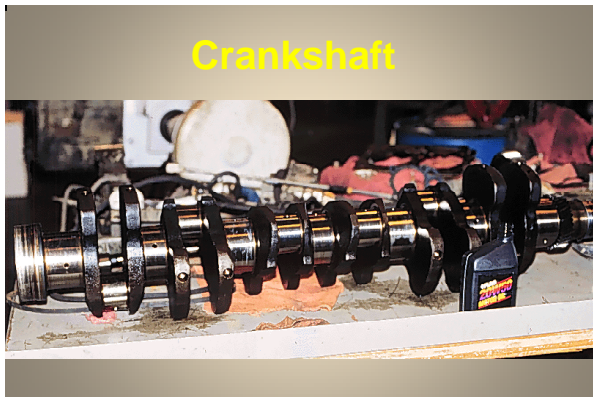


NACT 271

Stationary Reciprocating Engines

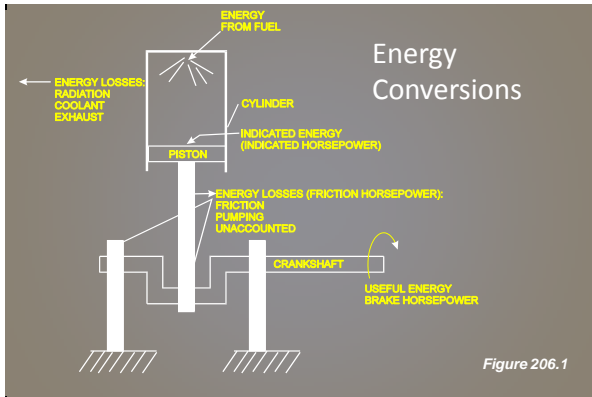






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Stationary Reciprocating Engines



What is Power?

- $Work = Distance \times Force$
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*
- $One\ Horsepower = 33,000\ ft\text{-}lb/min$

21

Rating Engine Power

- Horsepower
- Brake Horsepower
- Rated Brake Horsepower
- Kilowatts



22

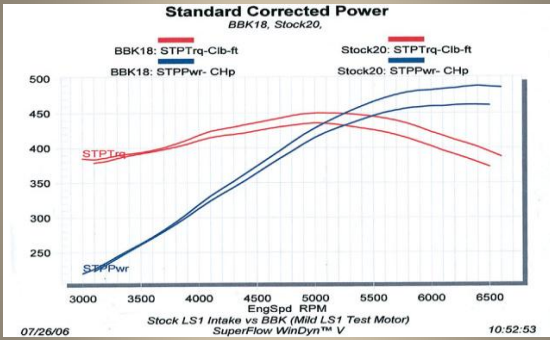
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Stationary Reciprocating Engines

Ways to Determine Horsepower

$$HP = \frac{\text{Mass flow rate of fuel (lb/hr or Btu/hr)}}{\text{Specific fuel consumption (lb/hp-hr or Btu/hp-hr)}} \quad \left. \vphantom{HP} \right\} \text{Fuel Consumption}$$

$$HP = \frac{\text{Torque (foot-lbs)} \times \text{RPM}}{5252} \quad \left. \vphantom{HP} \right\} \text{Engine Torque}$$



Comparison of S-I and C-I Engines

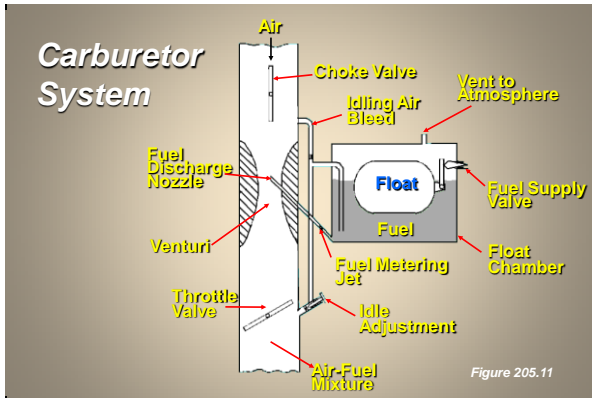
- Air/Fuel: C-I excess air only
S-I wide range of air/fuel
- Compression: C-I > S-I
- Efficiency: C-I > S-I
- Durability: C-I > S-I
- Emissions: C-I: NOx & PM
S-I: CO & NOx

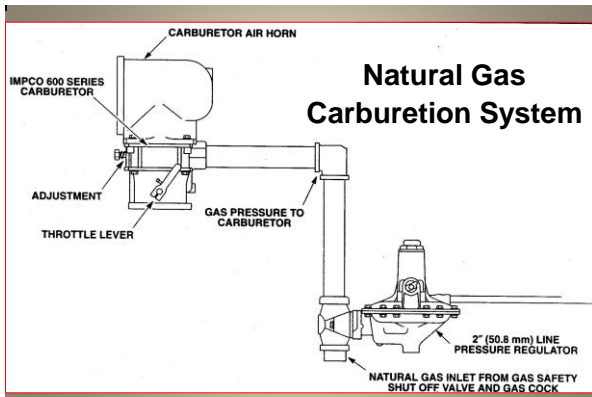
NACT 271

Stationary Reciprocating Engines

Air/Fuel Delivery Systems

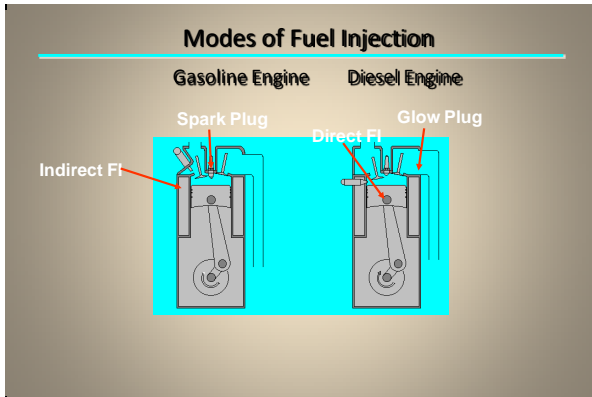
- Carburetor
- Gaseous Fuel Regulator
- Fuel Injection

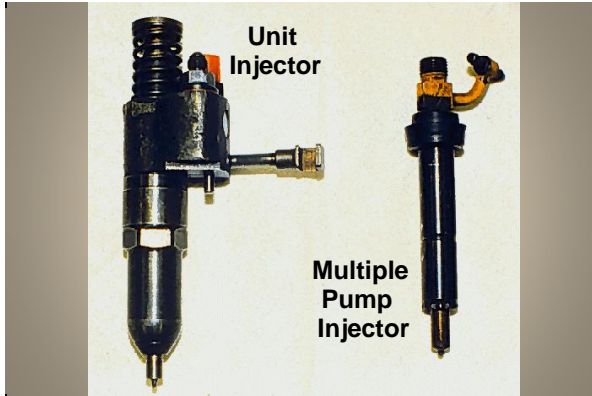


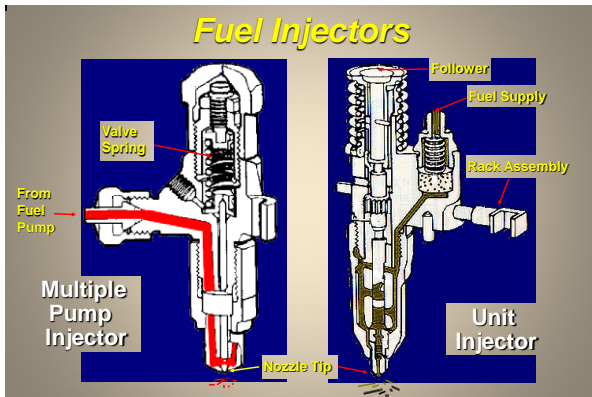


NACT 271

Stationary Reciprocating Engines

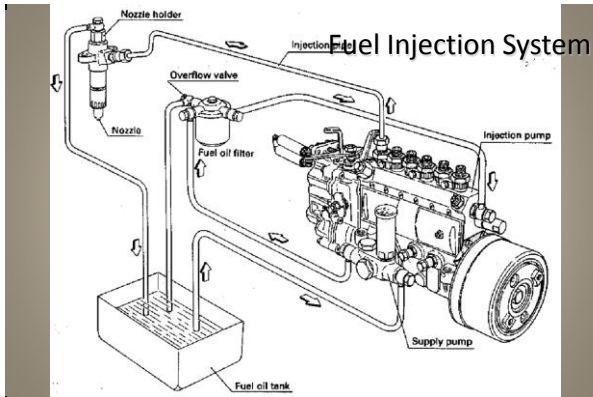




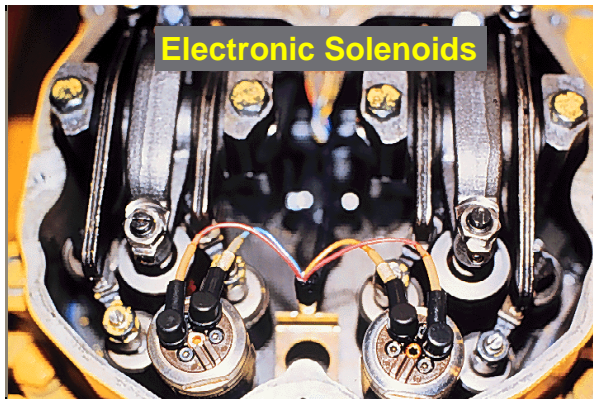


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Stationary Reciprocating Engines





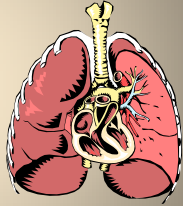


NACT 271

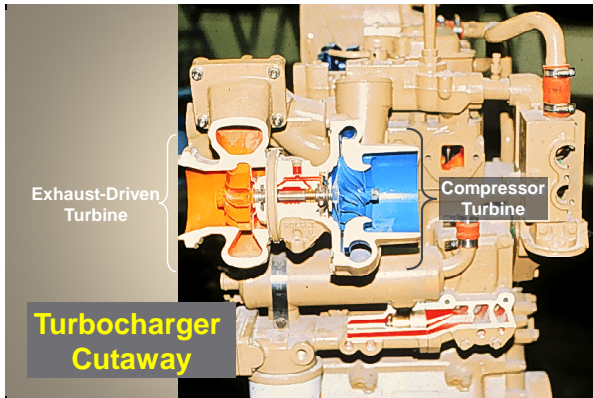
Stationary Reciprocating Engines

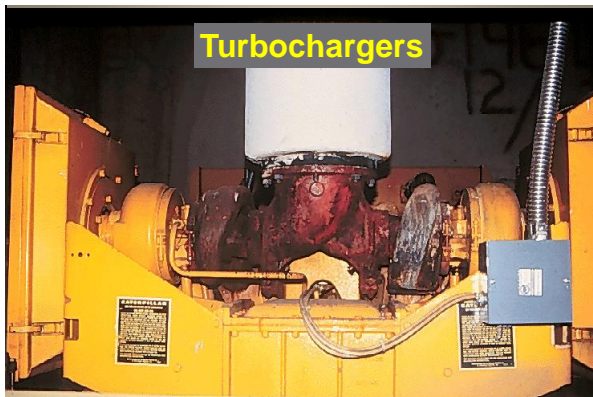
Increasing Air Intake

- Turbochargers
- Superchargers
- Blower-Scavenging



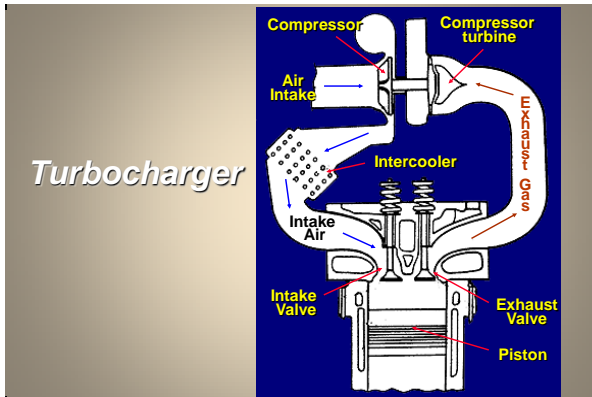
36





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Stationary Reciprocating Engines

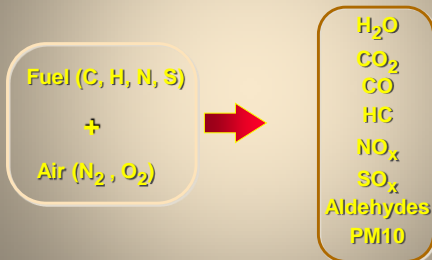


Intercooler

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

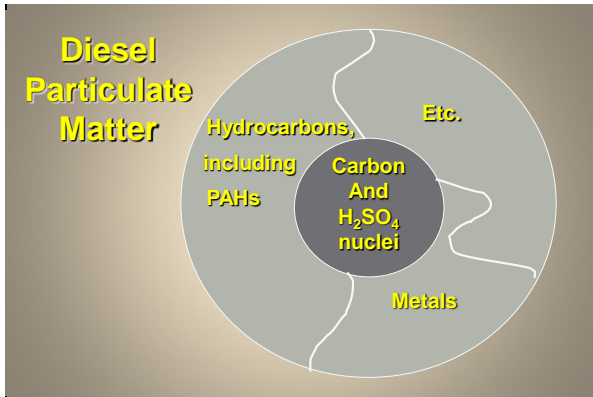


Emissions From SREs



NACT 271

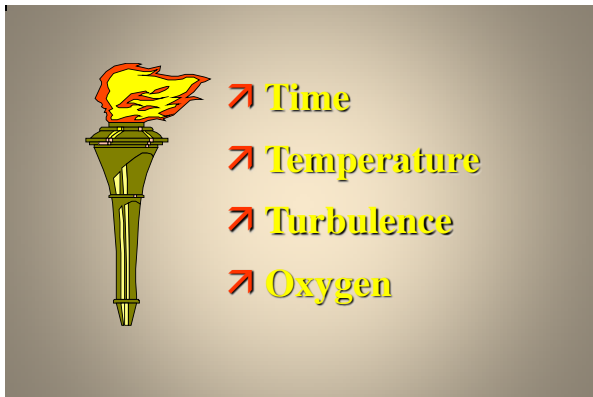
Stationary Reciprocating Engines



National Baseline HAP Emissions from RICE Units
2005

Type of Engine	Baseline HAP Emissions from All RICE Sources (tons/yr)	Baseline HAP Emissions from Major Sources (tons/yr)
Existing Engines:		
2SLB Clean Gaseous Fuel	13,888	5,555
4SLB Clean Gaseous Fuel	11,729	4,692
4SRB Clean Gaseous Fuel	838	335
Compression Ignition	1,034	414
Subtotal	27,489	10,996
New Engines:		
2SLB Clean Gaseous Fuel	1,565	626
4SLB Clean Gaseous Fuel	15,685	6,274
4SRB Clean Gaseous Fuel	785	314
Compression Ignition	1,165	466
Subtotal	19,200	7,680
Total	46,689	18,676

45



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Stationary Reciprocating Engines

Stoichiometric Ratio

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

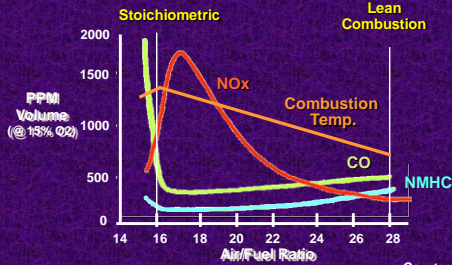
For Gasoline:

	AIR	FUEL
MASS	14.7	1
VOLUME	11,500	1

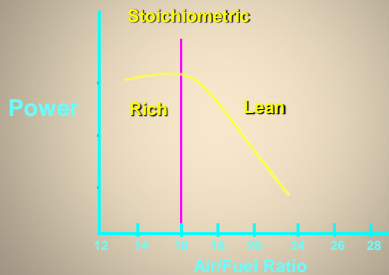
RICH = Less than 14.7:1
LEAN = Greater than 14.7:1



Exhaust Emissions and A/F (Natural Gas Engine)

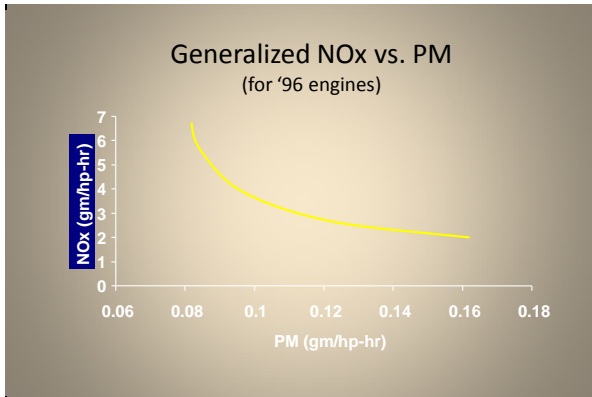


Engine Power and A/F



NACT 271

Stationary Reciprocating Engines



Mechanisms of Formation

CO	Incomplete combustion
NO_x	High temperature combustion of N ₂
HC	Unburned or partially burned fuel
SO_x	Oxidation of sulfur
PM₁₀	Partial combustion of engine oil Partially burned fuel

51

- ### Factors Affecting Emissions
- Engine Design
 - Fuel Type
 - Atmospheric Conditions
 - Operating Conditions
 - Tuning and Maintenance.
- 52

NACT 271

Stationary Reciprocating Engines

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

Emission Control Methods for Compression-Ignited Engines

PM Control

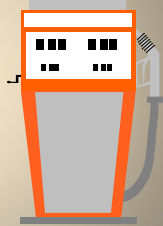
- Alternate Fuels
- Modified Injectors
- Diesel Oxidation Catalyst
- Diesel Particulate Filters
- Fuel-Borne Catalyst

NACT 271

Stationary Reciprocating Engines

Fuel Type

- Gaseous Fuels
- Diesel
- Liquid Fuels
- Alternate Fuels



Reciprocating Engine Typical Emission Levels

Engine Type	Lambda*(ε)	Mode	Emission (g/bhp-hr)			
			NMHC	CO	NOx	PM
Natural Gas	0.98	Rich	0.3	13.9	8.3	Low
	0.99	Rich	0.2	8.0	11.0	Low
	1.06	Lean	1.0	1.0	18.0	Low
	1.74	Lean	1.0	3.0	0.7	Low
Diesel	1.6-3.2	Lean	0.3	1.0	11.6	0.25-0.8
Dual Fuel	1.6-1.9	Lean	0.5	2.5	4.1	NA

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

Percentages of Gases in Gaseous Fuels

% in Fuel:	Type of Gaseous Fuel			
	Natural	Propane	Digester	Landfill
Methane	95%	---	65%	55%
Ethane	3%	4%	---	---
Propane	1%	95%	---	---
Butane+	1%	1%	---	---
CO2	---	---	35%	45%

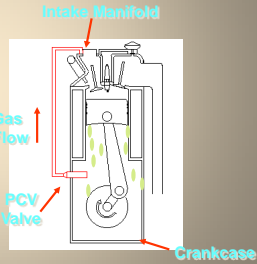
Courtesy Waukesha

NACT 271

Stationary Reciprocating Engines

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



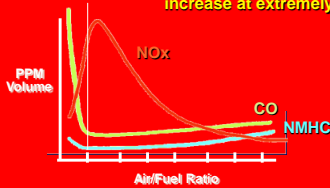
Air-Fuel Ratio Adjustment

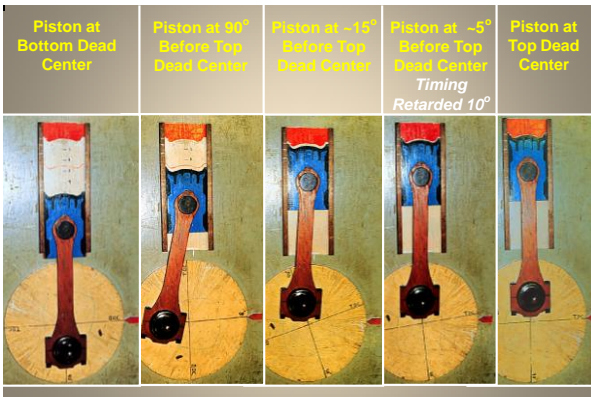
Rich Adjustment

Decrease NO_x by decrease O₂
 + cooling by excess fuel
 Increase HC, CO
 May increase fuel consumption

Lean Adjustment

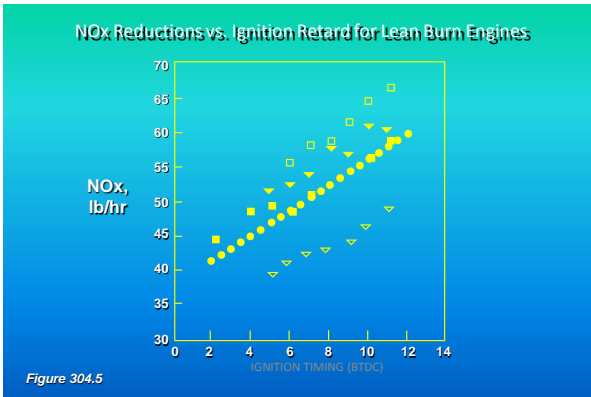
Decrease NO_x by decrease temp
 Increase fuel efficiency at mod.
 lean operation
 HC, CO, fuel consumption may
 increase at extremely lean

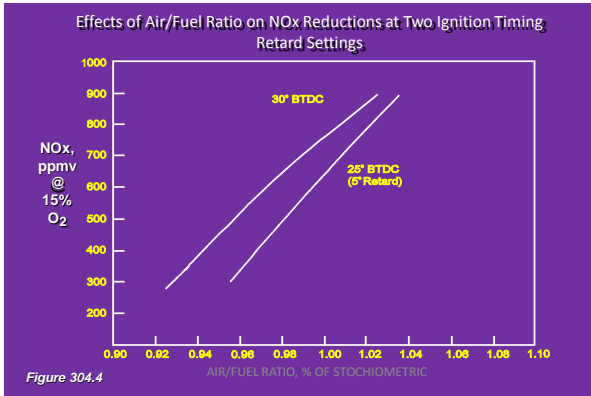




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Stationary Reciprocating Engines





Timing Retard

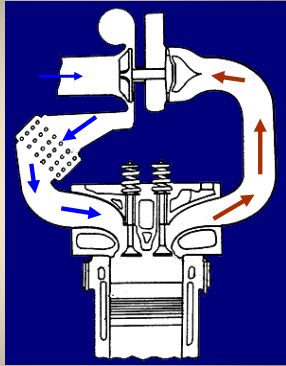
- NOx control by lowering combustion temperature
- Indicated by degrees of crankshaft rotation
- Injection TR for C-I / Ignition TR for S-I

<p>Advantages</p> <ul style="list-style-type: none"> low capital, operating costs easy to adjust minimal increase CO, HC 	<p>Disadvantages</p> <ul style="list-style-type: none"> reduce max power output reduce fuel efficiency may increase PM (smoke) in C-I may increase exhaust temps
--	---

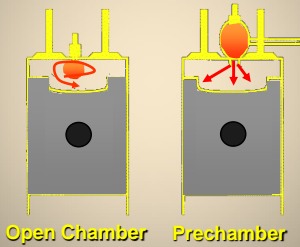
NACT 271

Stationary Reciprocating Engines

Turbocharger with Intercooler



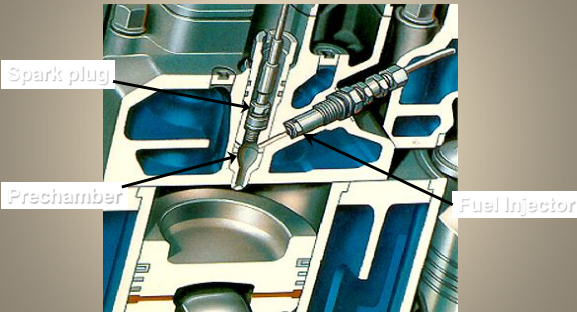
Low-Emission Combustion or "CleanBurn®" Engine



Open Chamber Prechamber

Courtesy Waukesha

Pre-Chamber System

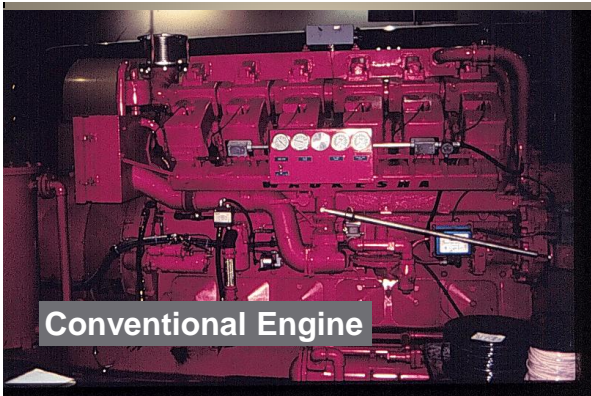


Courtesy Waukesha

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Stationary Reciprocating Engines

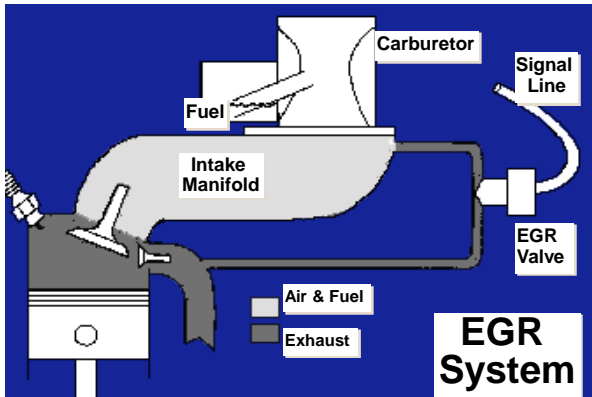


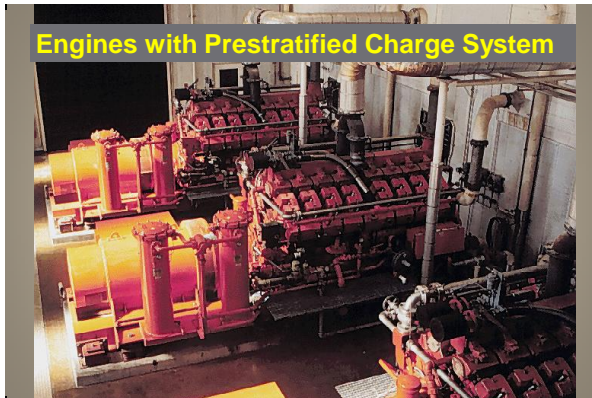


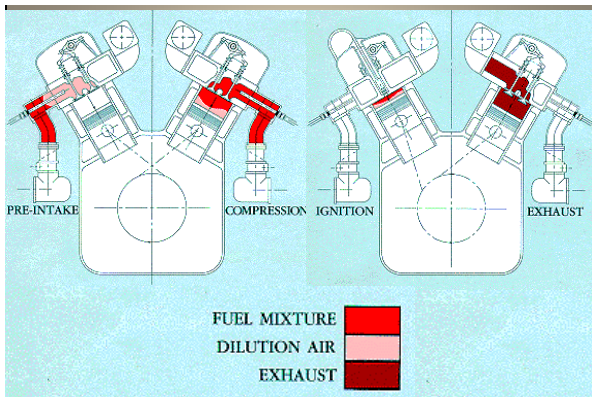


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Stationary Reciprocating Engines







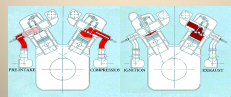
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Stationary Reciprocating Engines



Pre-Stratified Charge: Key Points

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



76

Catalytic Converters

CO is oxidized \rightarrow CO₂
HC is oxidized \rightarrow H₂O

} OXIDATION CATALYST
(Pt, Pd)

NO_x is reduced \rightarrow N₂

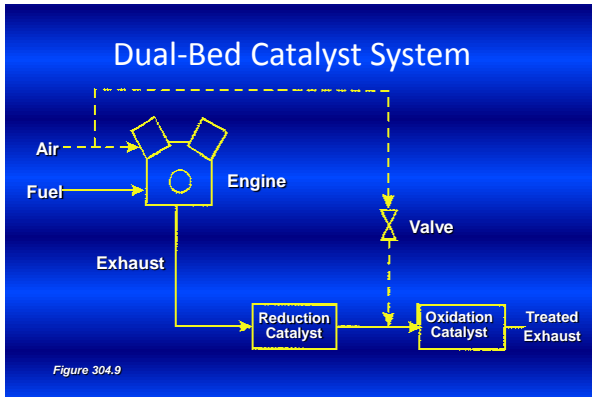
} REDUCTION CATALYST
(Rh)

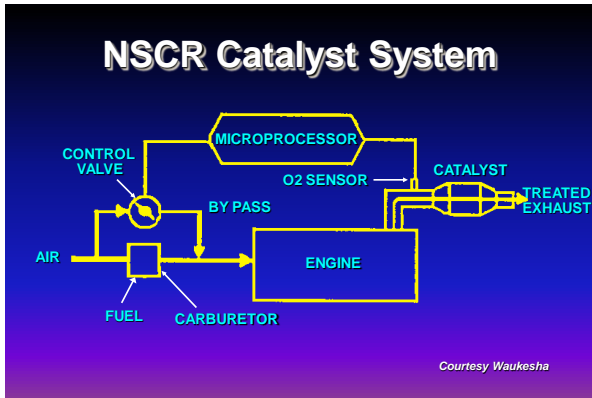
CO + HC + NO_x \rightarrow CO₂ + H₂O + N₂

} THREE-WAY or NON-SELECTIVE CATALYST

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Stationary Reciprocating Engines



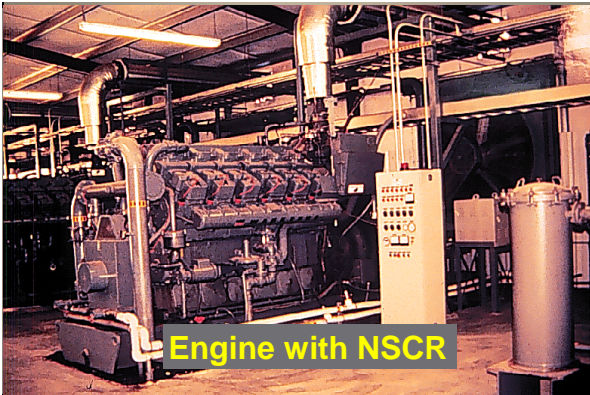


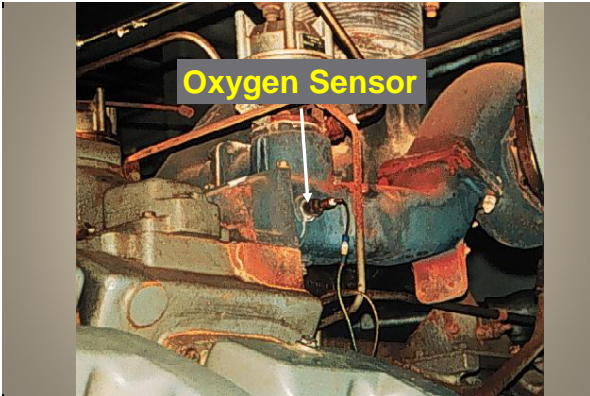
Non-Selective Catalytic Reduction (NSCR)

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

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Stationary Reciprocating Engines

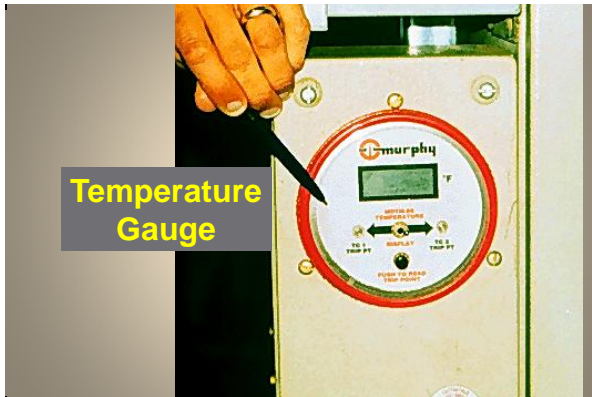


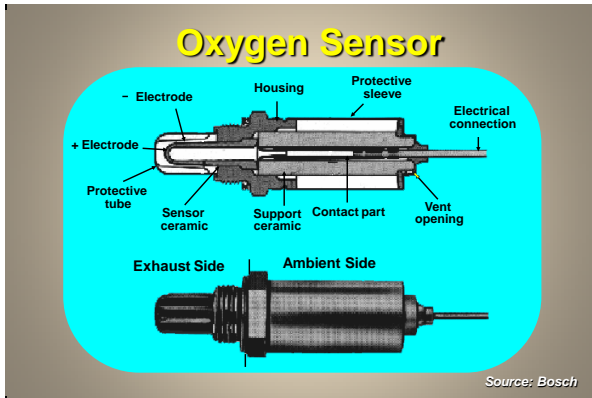




NACT 271

Stationary Reciprocating Engines





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

86

NACT 271

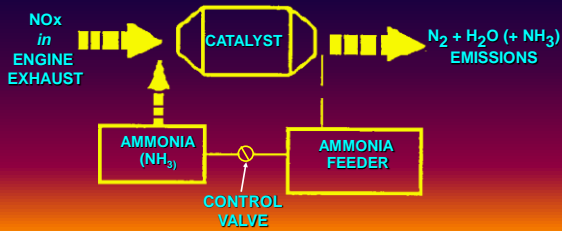
Stationary Reciprocating Engines

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

87

SCR System



Courtesy Waukesha

Major Parts of SCR System

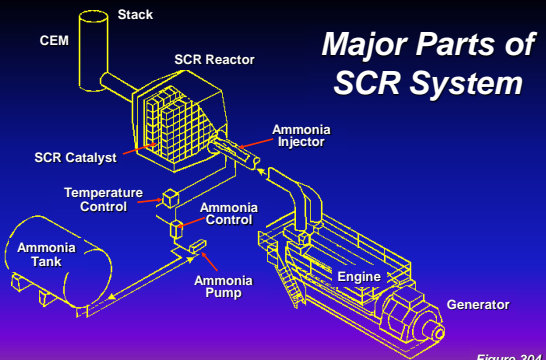
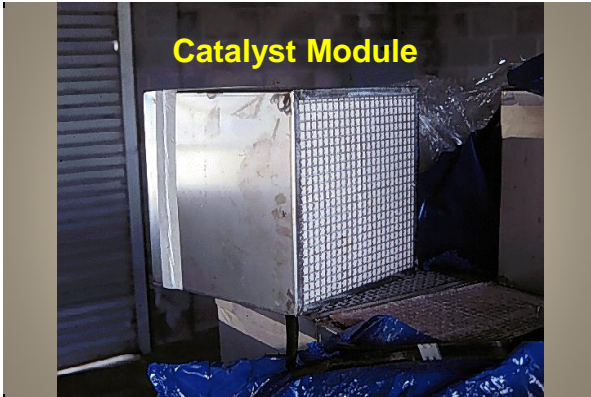


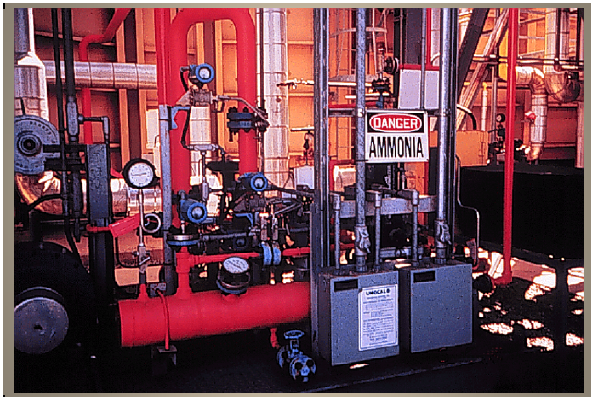
Figure 304.7

NACT 271

Stationary Reciprocating Engines





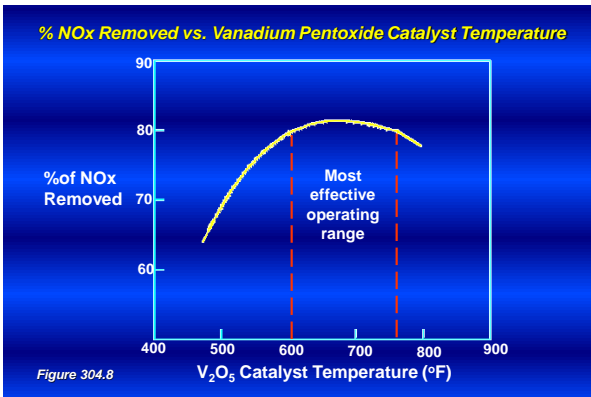


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Stationary Reciprocating Engines







NACT 271

Stationary Reciprocating Engines

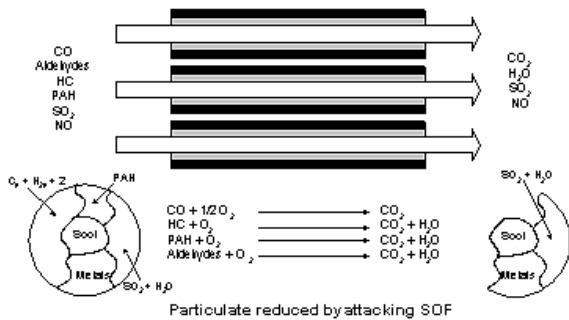
Selective Catalytic Reduction (SCR)

- 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)



NACT 271

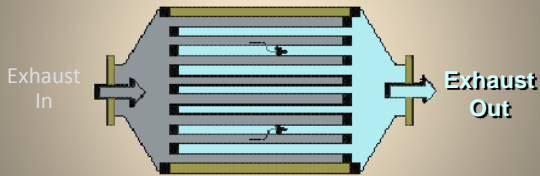
Stationary Reciprocating Engines

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 → adsorbs → reduces regeneration temperature
 - Fuel-borne catalyst
 - Ceramic coatings
 - Engine adjustments

99

Diesel Particulate Filter



100



NACT 271

Stationary Reciprocating Engines

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.

104

NACT 271

Stationary Reciprocating Engines

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

Date	Rule	Type of engines covered
June 2004	NESHAP	•Existing/new engines >500 HP at major sources
June 2006	NSPS	•New CI engines
January 2008	NSPS	•New SI engines
	NESHAP	•New engines •≤500 HP at major sources •all HP at area sources
March 2010	NESHAP	•Existing CI engines •≤500 HP at major sources •all HP at area sources •non-emergency CI >500 HP at major sources
August 2010	NESHAP	•Existing SI engines •≤500 HP at major sources •all HP at area sources
June 2011	NSPS	•Amendments for CI and SI engines
January 2013	NESHAP and NSPS	•Reconsideration of 2010 NESHAP •Minor amendments to NSPS for CI and SI engines

Applicability

RICE NESHAP	<ul style="list-style-type: none"> • Applies to stationary CI and SI engines, both existing and new
CI ICE NSPS	<ul style="list-style-type: none"> • Applies to stationary CI engines: • Ordered after July 11, 2005 and manufactured after April 1, 2006 • Modified or reconstructed after July 11, 2005
SI ICE NSPS	<ul style="list-style-type: none"> • Applies to stationary SI engines: • Ordered after June 12, 2006 and manufactured on/after • July 1, 2007 if ≥500 HP (except lean burn 500±HP<1,350) • January 1, 2008 if lean burn 500±HP<1,350 • July 1, 2008 if ~500 HP • January 1, 2009 if emergency >25 HP • Modified or reconstructed after June 12, 2006

NACT 271

Stationary Reciprocating Engines

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

Stationary RICE NESHAP



RICE NESHAP Background

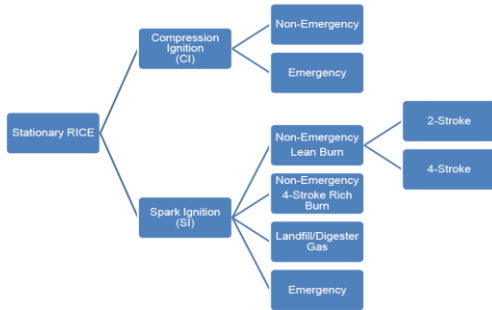
- ▶ Regulates HAP emissions from stationary RICE at both major and area sources of HAP
 - ▶ Major: ≥ 10 tons/year single HAP or ≥ 25 tons/year total HAP
 - ▶ Area: not major
- ▶ All sizes of engines are covered



NACT 271

Stationary Reciprocating Engines

General Subcategorization Approach



Existing vs. 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, religions establishments, police stations, fire stations

More info: http://www.epa.gov/ttn/atw/rice/guidance_emergency_engine_def.pdf

NACT 271

Stationary Reciprocating Engines

Emission Standards: Existing RICE at Major Sources

HP	Engine Subcategory					Emergency
	Non-emergency					
	CI	SI 2SLB	SI 4SLB	SI 4SRB	SI LFG/DG	
<100	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					Change oil/filter & inspect hoses/belts every 500 hours or annually; inspect air cleaner (CI) or spark plugs (SI) every 1,000 hours or annually
100-300	230 ppm CO	225 ppm CO	47 ppm CO	10.3 ppm CH ₂ O	177 ppm CO	
300-500	49 ppm CO or 70% CO reduction					
>500	23 ppm CO or 70% CO reduction	No standards	No standards	350 ppb CH ₂ O or 76% CH ₂ O reduction	No standards	No standards

Note: Existing limited use engines >500 HP at major sources do not have to meet any emission standards. Existing black start engines <500 HP at major sources must meet work practice standards.

35

Emission Standards – New RICE at Major Sources

HP	Engine Subcategory					Emergency
	Non-emergency					
	CI	SI 2SLB	SI 4SLB	SI 4SRB	SI LFG/DG	
<250	Comply with CI NSPS	Comply with SI NSPS	Comply with SI NSPS	Comply with SI NSPS	Comply with SI NSPS	Comply with CI/SI NSPS
250-500			14 ppm CH ₂ O or 93% CO reduction			
>500	580 ppb CH ₂ O or 70% CO reduction	12 ppm CH ₂ O or 58% CO reduction		350 ppb CH ₂ O or 76% CH ₂ O reduction	No standards	No standards

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

39

Compliance Requirements: RICE at Major Sources

Engine Subcategory	Compliance Requirements
Existing non-emergency: •CI ≥100 HP at major source •SI 100-500 HP at major source	<ul style="list-style-type: none"> •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) <p>Existing non-emergency CI >300 HP:</p> <ul style="list-style-type: none"> •Ultra low sulfur diesel (ULSD) •Crankcase emission control requirements

40

NACT 271

Stationary Reciprocating Engines

Compliance Requirements: Non-Emergency Engines at Area Sources

Engine Subcategory	Compliance Requirements
<ul style="list-style-type: none">Existing non-emergency CI >300 HP at area source	<ul style="list-style-type: none">Initial emission performance testSubsequent 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 HPNotificationsSemiannual compliance reports (annual if limited use)Ultra low sulfur diesel (ULSD)Crankcase emission control requirements
<ul style="list-style-type: none">Existing non-emergency SI 4SLB/4SRB >500 HP at area source used >24 hours/year and not in remote area	<ul style="list-style-type: none">Initial and annual catalyst activity checksHigh temperature engine shutdown or continuously monitor catalyst inlet temperatureNotificationsSemiannual compliance reports

19

Compliance Requirements: Non-Emergency Engines at Area Sources

Engine Subcategory	Compliance Requirements
<u>Existing non-emergency:</u> <ul style="list-style-type: none">black start at area sourceCI ≤300 HP at area sourceSI ≤500 HP at area sourceSI 2SLB >500 HP at area sourceSI LFG/DG >500 HP at area sourceSI 4SLB/4SRB >500 HP at area source used ≤24 hours/year or in remote area	<ul style="list-style-type: none">Operate/maintain engine & control device per manufacturer's instructions or owner-developed maintenance planMay use oil analysis program instead of prescribed oil change frequencyKeep records of maintenanceNotifications not required

20

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

NACT 271

Stationary Reciprocating Engines

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 (CI) 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 IIII if CI; part 60 subpart JJJJ if SI

13

Oil Analysis Programs

Parameter	Condemning Limits
Total Base Number (CI RICE only)	<30% of the TBN of the oil when new
Total Acid Number (SI RICE only)	Increases by more than 3.0 mg of potassium hydroxide per gram from TAN of the oil when new
Viscosity	Changed by more than 20% from the viscosity of the oil when new
% Water Content by volume	>0.5

- ▶ 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

14

NACT 271

Stationary Reciprocating Engines

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>

16

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

21

NACT 271

Stationary Reciprocating 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



25

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



26

NACT 271

Stationary Reciprocating Engines

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

23

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

24

Fuel Requirements

Date	Requirement
October 1, 2007	Low sulfur diesel (LSD)
October 1, 2010	Ultra low sulfur diesel (ULSD)
Engines <30 liters/cylinder displacement	•Max sulfur content 15 ppm •Minimum cetane index of 40 or max aromatic content of 35 volume %
June 1, 2012	1,000 ppm sulfur diesel
Engines ≥30 liters/cylinder displacement	

25

NACT 271

Stationary Reciprocating Engines

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



26

	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY 2012 MODEL YEAR CERTIFICATE OF CONFORMITY WITH THE CLEAN AIR ACT OF 1990	OFFICE OF TRANSPORTATION AND AIR QUALITY ANN ARBOR, MICHIGAN 48105
Certificate Issued To: Perkins Engines Co Ltd (i.e., Manufacturer or Importer) Certificate Number: C19C1A.020-1-007	Effective Date: 09/02/2011 Expiration Date: 11/12/2011	Issued Date: 09/02/2011 Revision Date: N/A
Model Year: 2012 Manufacturer Type: Original Engine Manufacturer Engine Family: C19C1A.020	Multi-Stationary Indicator: Stationary Engine Power Category: 19-300-1100 Fuel Type: Non-Derived Fuel, Diesel After Treatment Device(s): After Treatment Device(s) Installed Non-After Treatment Device(s): Non-After Treatment Device(s) Installed	
<p><small>Permitted by Section 111 and Section 213 of the Clean Air Act (40 C.F.R. sections 70.11 and 70.17) and 40 C.F.R. Part 60, and subject to the terms and conditions prescribed in these provisions, this certificate of conformity is hereby issued with respect to the test engines which have been found to conform to applicable requirements and which represent the following engines, by engine family, more fully described in the documentation required by 40 C.F.R. Part 60 and produced in the stated model year.</small></p> <p><small>This certificate of conformity covers only new non-combustion engines which conform in all material respects to the design specifications that applied to these engines described in the documentation required by 40 C.F.R. Part 60, and which are produced during the model year stated on this certificate of conformity and manufactured, or subject to, 40 C.F.R. Part 60.</small></p> <p><small>It is a term of this certificate that the manufacturer shall conform to all requirements described in 40 C.F.R. Part 60 and applicable to a machine or unit and that failure to comply with the requirements of such a machine or unit may lead to revocation or suspension of this certificate for reasons specified in 40 C.F.R. Part 60. It is also a term of this certificate that this certificate may be revoked or suspended or limited with or without notice for reasons specified in 40 C.F.R. Part 60.</small></p> <p><small>This certificate does not cover engines sold, offered for sale, or introduced, or delivered, for introduction into commerce in the U.S. prior to the effective date of the certificate.</small></p>		

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
 - ▶ If operate differently than manufacturer's recommendations, must do performance test to show compliance
- ▶ Displacement ≥30 liters/cylinder
 - ▶ Initial performance test
 - ▶ Annual performance test for non-emergency engine
 - ▶ Continuously monitor operating parameters

*For CI fire pump engine, 2008-2011 model year and later (depending on engine size)

28

NACT 271

Stationary Reciprocating Engines

Monitoring/Recordkeeping/Reporting

Engine Type	Requirement
Emergency Engines	•Non-resettable hour meter and records of operation if engine does not meet non-emergency engine standards
Equipped with diesel particulate filter (DPF)	•Backpressure monitor and records of corrective actions
Non-emergency >3,000 HP or with displacement >10 liters/cylinder and Pre-2007 model year >175 HP that are not certified	•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

29

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



41

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

31

NACT 271

Stationary Reciprocating Engines

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: NO_x, CO, VOC
- ▶ Some standards modeled after EPA's standards for nonroad SI engines



44

Emission Standards (In General)

Engine	Standards
≤25 HP (all engines)	Part 90 or part 1054 standards for new nonroad SI engines
Non-emergency gasoline and rich burn LPG	Part 1048 standards for new nonroad SI engines
Non-emergency natural gas and lean burn LPG 25<HP<100	Part 1048 standards for new nonroad SI engines (or other options)
≥100 HP and not gasoline or rich burn LPG	Standards in Table 1 of subpart JJJJ, part 1048 standards for some engines

Owners/operators of gasoline engines must use gasoline that meets the sulfur limit in 40 CFR 80.195 – cap of 80 ppm

32

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
 - 100≤HP≤500 – initial performance test
 - >500 HP – initial performance test and subsequent every 8,760 hours or 3 years, whichever is first

33

NACT 271

Stationary Reciprocating Engines

Compliance Requirements for Owners/Operators

- ▶ **Non-certified engines:**
 - ▶ Maintenance plan
 - ▶ Performance testing
 - 25-HP≤500 – 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

34

EPA Region	Geographic Area	Contact	Phone	Email
Region I	CT, MA, ME, NH, RI, VT	Susan Lancey	(617) 918-1656	lancey.susan@epa.gov
		Roy Crystal	(617) 918-1745	crystal.roy@epa.gov
Region II	NJ, NY, PR, VI	Umesh Dholakia	(212) 637-4023	dholakia.umesh@epa.gov
Region III	DE, MD, PA, VA, WV, DC	Ray Chalmers	(215) 814-2746	chalmers.ray@epa.gov
Region IV	FL, NC, SC, KY, TN, GA, AL, MS	Lee Page	(404) 562-9131	page.lee@epa.gov
Region V	IL, IN, WI, MI, OH, MN	Rae Trine	(312) 353-9228	trine.rae@epa.gov
		Nathan Frank	(312) 886-3850	frank.nathan@epa.gov
		Sara Breneman	(312) 886-0243	breneman.sara@epa.gov
		William MacDowell	(312) 886-6798	macdowell.william@epa.gov
Region VI	AR, LA, NM, OK, TX	Donald M. Smith	(214) 665-7270	smith.donald-m@epa.gov
		Tony Robledo	(214) 665-8182	robledo.tony@epa.gov
Region VII	IA, KS, MO, NE	Leslye Werner	(913) 551-7858	werner.leslye@epa.gov
		David Peter	(913) 551-7397	peter[mailto:werner.leslye@epa.gov]
Region VIII	CO, MT, ND, SD, UT, WY	Alexis North	(303) 312-7005	north.alexis@epa.gov
Region IX	CA, AZ, HI, NV, GU, AS, MP	Periann Wood	(415) 947-4138	wood.periann@epa.gov
		Lisa Beckham	(415) 972-3811	beckham.lisa@epa.gov
Region X	AK, ID, WA, OR	Heather Valdez	(206) 553-6220	valdez.heather@epa.gov

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

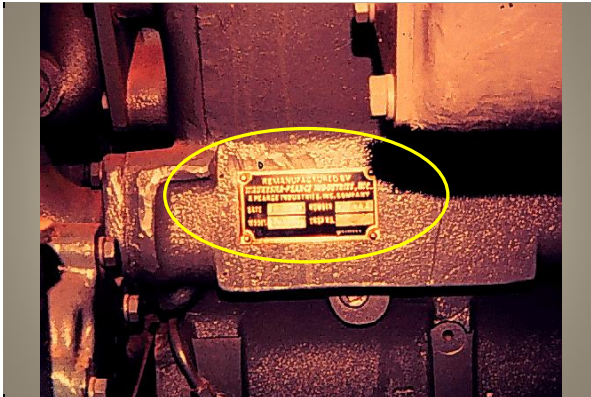
Inspection

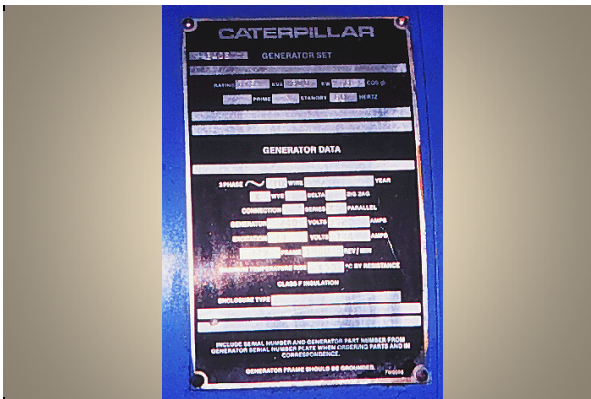
- Visible Emissions Evaluation
- General Upkeep and Maintenance
- Monitoring Instruments (operation, records)
- Fuel Type, Quality (records, samples)
- Control Devices
- Maintenance Records

NACT 271 Stationary Reciprocating Engines

Inspection (con't.)

- Emissions Screening
- Source Test
- Timing Check
- Derating Verification





NACT 271

Stationary Reciprocating Engines





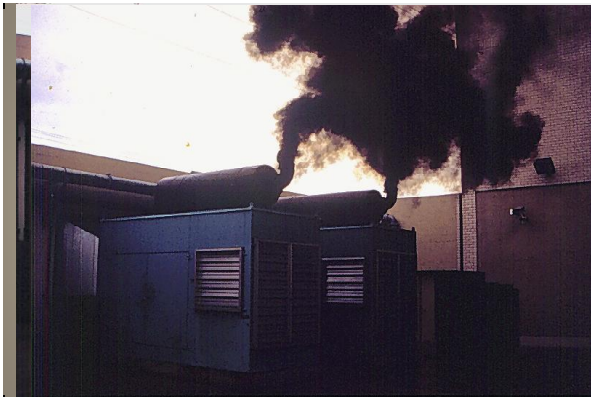


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Stationary Reciprocating Engines

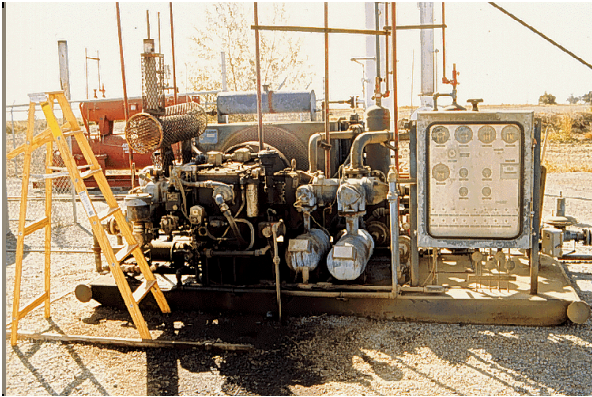






NACT 271

Stationary Reciprocating Engines







NACT 271

Stationary Reciprocating Engines







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/region1/rice/
- www.combustionportal.org