EPA Nonroad Vehicle and Engine Program

Society of Automotive Engineers and U.S. Department of Energy

Off-Highway Emissions and Systems Efficiency Workshop

for Heavy Vehicles

U.S. Environmental Protection Agency

Office of Transportation and Air Quality

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Cleophas Jackson
Overview of Briefing

- Nonroad is a big source of pollution
- We’ve come a long way
- We’ve got a ways to go
- We’re working on it!
Overview, continued

- Background
- Historical context and statutory authority
- Inventory
- Current nonroad programs
- Future programs
Background: What is Nonroad?

- Non-highway engines, vehicles, & equipment that move or can be moved
- More than 80 basic categories (agricultural, construction, marine, etc.)
- EPA’s NONROAD model covers 462 specific equipment types, not including locomotives, aircraft, commercial marine
- Complicated industry structure: hundreds of manufacturers, many of them very small
Major Nonroad Equipment Types

- Aircraft
- Airport service
- Agricultural
- Commercial
- Commercial marine
- Construction
- Industrial

- Lawn & garden (com & res)
- Locomotives
- Logging
- Railroad service
- Recreational vehicles
- Recreational marine
Historical & Statutory Context

- No EPA program prior to 1990 Clean Air Act
- Section 213 of 1990 Act directed EPA to:
  - evaluate contribution of nonroad sources to urban nonattainment
  - adopt standards if warranted
  - consider comparable highway standards in determining stringency
  - achieve greatest emission reduction possible considering cost, safety, etc.
  - regulate any nonroad category that contributes to air pollution
- Section 209 of 1990 Act:
  - preempts all state regulation of locomotives and of farm and construction equipment <175 hp
  - allows California to set independent standards for other nonroad sources, with authorization from EPA Administrator
  - allows other states to adopt California standards
- Section 231 covers aircraft separately
1991 “NEVES” study found nonroad sources significant to ozone and CO nonattainment, also major source of PM

EPA initiated comprehensive nonroad program

Approach: do what makes sense, get big reductions first
- model and inventory development
- regulations
- education and voluntary programs
  » industry
  » consumers

“Finding” process complete for all categories
Nonroad Contributions to Total Inventory (1996)

- Nonroad sources contribute significantly to NOx, PM, and VOC emissions
- Locomotives, construction and farm equipment are largest sources of NOx
- Construction and farm equipment are largest sources of PM
- Lawn, garden and recreational marine equipment are largest sources of VOC
Impact of Controls on 2000 - 2007 Inventory

Percent of 2000 Emissions

NOx  PM  HC

2000  2007

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2007 NOx Inventories

Mobile Sources

~10 million tons per year

Nonroad

~5 million tons per year

Nonroad

Highway 54%

Nonroad 46%

Land-based Diesel 47%

Large SI 8%

Other 8%

Locomotives 16%

Marine Diesel 21%

~10 million tons per year

~5 million tons per year
2007 HC Inventories

**Mobile Sources**

- ~5 million tons per year

**Nonroad**

- ~2.6 million tons per year

- Highway 44%
- Nonroad 56%
- Land-based Diesel 7%
- Large SI 5%
- Marine SI 25%
- Rec. Vehicles 21%
- Other 10%
- Small SI 32%
2007 PM Inventories

Mobile Sources

~600,000 tons per year

Nonroad

~420,000 tons per year

Nonroad

Other
11%

Marine Diesel
10%

Marine SI
8%

Land-based Diesel
52%

Locomotives
6%

Small SI
13%

Nonroad
70%

Highway
30%

Nonroad
70%
2007 CO Inventories

Mobile Sources
~ 77 million tons per year

Nonroad
~ 30 million tons per year

- Nonroad 43%
- Highway 57%
- Other 8%
- Rec. Vehicles 13%
- Marine SI 6%
- Large SI 8%
- Small SI 65%
Current Nonroad Programs

- Large nonroad diesel
- Locomotives
- Marine engine programs (commercial/recreational)
- Lawn & garden engines
- Industrial gasoline engines
- Recreational vehicles
Large Nonroad Diesel Engines

- Compression-ignition (CI) engines, mostly diesel-fueled
- Construction and farm equipment but other categories also
- About 10% of current total NOx & PM inventories
- 3-step regulatory program in place
  - Tier 1 FRM 1994
    » modest NOx control phasing in between 1996 and 2000
    » ~30% NOx reduction from uncontrolled
  - Tier 2 & 3 FRM 1998
    » more stringent NOx standards, also HC, CO, PM, implemented 1999 - 2008
    » 60% NOx and 40% PM reduction relative to Tier 1
  - Tier 3 ANPRM expected 2001
    » revisits ‘98 FRM; feasibility review underway to assess appropriate PM standards
    » expected to cover range of operation, “typical” transient test cycle
Comparison of Nonroad and Highway Controls and Technology

Nonroad

Nonroad Tier 4
Nonroad Tier 3
Nonroad Tier 2
Nonroad Tier 1

Fuel Sulfur

Highway

Highway 2007
Highway 2004
1996
1990

< 15 ppm
500 ppm
Large Nonroad Diesel: Next Steps

- The goal is to move the nonroad sector closer to highway emissions levels assuming the availability of the appropriate fuel.
- Technology transfer from the highway applications to nonroad applications first in 100 to 750 hp range.
- Some applications may be more suited to transfer sooner - such as those higher volume or those without significant design constraints.
Locomotives currently emit over one million tons of NOx each year in the U.S. --about 5 percent of total NOx emitted by all U.S. mobile sources.

Final emission standards published April, 1998
- Primary focus was to reduce NOx emissions--reducing HC and PM was secondary
- Emission standards apply to most post-1972 locomotives when they become new (at manufacture and remanufacture)
- Standards apply throughout useful life

Rulemaking established some innovative requirements
- Certification of remanufactured locomotives
- Notch standards
- Minimum useful life
- In-use testing
- In-use maintenance requirements for operators
Locomotives, continued

- Emission standards phase in beginning January 2000
- One of three sets of standards apply depending on a locomotive's original manufacturing date (all percents relative to baseline):
  - Tier 0 (1973-2001 locomotives) 34% NOx reduction
  - Tier 1 (2002-2004 locomotives) 49% NOx reduction
  - Tier 2 (2005+ locomotives) 62% NOx, 50% PM and HC reductions
- All locomotives must comply over two distinct duty-cycles (except Tier 0 switch locomotives):
  - high-power duty-cycle based on typical line-haul operation
  - low-power duty-cycle based on typical switch operation
Projected Locomotive Emissions

HC and PM Emissions

HC

PM

NOx

NOx Emissions

HC and PM Emissions per Year

Thousand Metric Tons per Year

2000 2010 2020 2030 2040

10 15 20 25 30 35

40 45

1000 1100 1200

900 800 700

600 500

400 300 200 100

10
IMO MARPOL Annex VI adopted in 1997

- applies to marine diesel engines >130 kW
- takes effect when 15+ countries representing 50% tonnage have ratified
- Regulation 13 limits for NOx apply to engines installed or modified after January 2000

Maximum Allowable NOx Emissions
For Marine Diesel Engines
(Regulation 13 NOx Curve)
Commercial Marine - U.S.

- FRM published December 1999 for engines over 37 kW
  - applies to new engines installed on U.S.-flagged vessels
  - Up to 30 liters/cylinder
  - Commercial only
  - Propulsion and auxiliary

- Doesn’t apply to:
  - Smaller marine diesel engines covered in the nonroad diesel Tier 2 rule (October 1998)
  - Engines made before the standards apply (most remanufacturing is unaffected)
  - Recreational engines
  - Engines on vessels that operate primarily outside U.S. waters
New EPA standards rely on technology transfer
- Standards for small engines (< 5 liters/cylinder) comparable to Tier 2 levels for land-based nonroad diesel engines
- Standards for large engines (5 to 30 liters/cylinder) comparable to Tier 2 levels for locomotive engines

Standards require manufacturers to control “off-cycle” emissions

Estimated reductions:
- 24 percent NOx
- 12 percent PM

EPA will propose emission standards for marine diesel engines over 30 liter/cylinder in April 2002
- This results from a settlement agreement to adopt standards for engines on U.S.-flagged ocean-going vessels
Recreational Marine Regulations

- **Outboards and Personal Watercraft October 1996 FRM**
  - 75% reduction in HC
  - conversion to 4-stroke engines and direct-injection 2-stroke engines

- **Sterndrive and Inboard Gasoline Marine Engines**
  - recently published ANPRM with FRM due in September 2002 (includes airboats and jetboats)
  - looking at automotive technology (fuel injection, EGR, catalysts)
  - most manufacturers are small businesses
    » convened SBREFA Panel in 1999
  - coordinating with the California Air Resources Board

- **Recreational Marine Diesel Engines**
  - included in recent ANPRM and 1999 SBREFA Panel
OB/PWC HC+NOx Emissions Inventory

Baseline

Controlled

Calendar Year

HC+NOx [1000 metric tons]
Lawn & Garden (“Small SI”)

- Regulations apply to engines under 25 hp
  - Primarily used in Lawn & Garden equipment

- Regulations apply to two broad categories
  - Engines used in Nonhandheld applications (e.g., lawnmowers, tractors, pumps, etc…)
  - Engines used in Handheld applications (e.g., string trimmers, leaf blowers, chainsaws, etc…)

- EPA adopted Phase 1 standards in 1995
  - Standards took effect in 1997
  - Standards represent a 32% reduction in HC (from pre-control levels)
Lawn & Garden, continued

- Nonhandheld Phase 2 final rule adopted March 1999
  - Emissions reduced 60 percent below Phase 1 levels
- Handheld Phase 2 final rule adopted March 2000
  - Emissions reduced 70 percent below Phase 1 levels
- Both handheld and nonhandheld Phase 2 standards:
  - Take effect between 2001-2007
  - Address emissions deterioration
  - Allow emissions averaging
  - Are based on full-life emissions
  - Manufacturers are required to test production line engines for compliance
Industrial ("Large SI")

- Proposal due September 14, 2001
- Equipment types:
  - forklifts, airport equipment, sweepers, aerial lifts
  - generators, pumps, compressors, saws, chippers
- Engine types
  - Large majority are derived from automotive engines
  - A few are air-cooled industrial engines
- Fuel types
  - 70 percent of engines use LPG
  - Gasoline is the alternative fuel
  - Fuel conversions and dual-fuel engines are common
California ARB adopted emission standards in October 1998
- 3 g/hp-hr NOx+NMHC standard phases in from 2001 through 2004
- Projected technology includes electronic fuel systems with 3-way catalyst
- Compliance program includes production-line and in-use testing by manufacturers

EPA proposal will likely be consistent with ARB, with a few remaining issues
- Level of emission standards
- Transient duty cycle
- Not-to-exceed provisions
- Basic engine diagnostics
- Evaporative emissions

Anticipating 80 to 90 percent reduction (NOx + HC)
Recreational Vehicles

- Proposal due September 14, 2001
- Three main vehicle types:
  - Off-road motorcycles, snowmobiles, and all-terrain vehicles (ATVs)
- EPA has not yet set standards for these vehicles. California has adopted “limited” standards for off-road motorcycles and ATVs
- We are also concerned about personal exposure to potentially high levels of CO and toxic emissions from these vehicles
EPA also released an ANPRM in November 2000 to start the standard-setting process.

EPA requests comment in several areas including:
- technologies that may be available to reduce emissions
- the timing and level of new emission standards
- test procedures for measuring emissions from vehicles and engines
- compliance programs
- competition provisions
Aircraft Authority

- CAA section 231 gives EPA authority to set emission standards
- CAA section 232 gives FAA authority to enforce these standards
- CAA section 233 preempts states from setting aircraft standards
Aircraft Emission Standards

- Aircraft engines are international commodities and frequently traverse national boundaries
  - ICAO process used in setting standards
- HC, NOx, and CO standards for jet engines greater than 26.7 kilonewtons of thrust (most mid to large commercial jets)
- Smoke standards for jet and turboprop engines
- EPA aligned with international standards (ICAO) in 1997
  - HC standards for all engines produced after 1983
  - CO standards for all engines produced after July 1997
  - NOx standards for newly designed engines after 1995 and all engines produced after 2000
- More stringent NOx standards adopted by ICAO in 1999, to be implemented for newly designed engines after 2003
  - We plan to align with these standards in the future
Aircraft Inventory

- Commercial aircraft component of regional mobile source emissions
- Nationally, NOx emissions expected to increase 25% between 1995 and 2020
- Aircraft emissions can have very significant local/regional impact
EPA/FAA Voluntary Emission Reduction Initiative

- EPA & FAA co-chairing national stakeholder process to develop voluntary program to reduce pollutants from aircraft and other aviation sources
- Study underway to assess existing and projected emissions
- Initiative to also evaluate control options
  - technological feasibility
  - cost effectiveness
- Possible options include retrofitting, low-pollution technology, efficient operating practices, GSE electrification
- Process to conclude by summer 2001
Other Nonroad Program Issues

- Harmonization
  - international
  - California

- Toxics
  - In general, any control that reduces PM and VOC emissions also reduces toxics
  - 202(l) rule calls for research plan to determine whether further, specific, control of nonroad toxics is feasible and warranted
Phase-In of Nonroad Control Programs

Current EPA Nonroad Control Program Phase-In Schedule

- **Industrial (large SI)**: 1997 - 2007
- **Lawn & Garden (small SI)**: 1998 - 2006
- **Commercial Marine**: 2000 - 2007
- **Locomotives**: 1997 - 2005
  - **Remanufacture standards apply to engines built since 1973**
- **Nonroad Diesel**: 1996 - 2008

**Phase-In Dates**
- 1995
- 2000
- 2005
- 2010
## Summary of Rulemaking Schedule

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<thead>
<tr>
<th>Category</th>
<th>Sales per year</th>
<th>Final Rules</th>
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<td>Aircraft engines</td>
<td>1,000</td>
<td>1982, 1997</td>
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<tr>
<td><strong>Land-based nonroad diesel</strong></td>
<td>360,000</td>
<td>1994, 1998</td>
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<tr>
<td>Locomotives</td>
<td>600</td>
<td>1998</td>
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<tr>
<td>Marine diesel --commercial</td>
<td>15,000</td>
<td>1999</td>
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<tr>
<td>Marine SI --outboard &amp; PWC</td>
<td>800,000</td>
<td>1996</td>
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<tr>
<td>Recreational marine</td>
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<td></td>
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<tr>
<td>--diesel and SD/I gasoline</td>
<td>120,000</td>
<td>September 2002</td>
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<tr>
<td>Lawn &amp; Garden SI &lt; 19 kW</td>
<td>15,000,000</td>
<td>1995, 1999</td>
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<tr>
<td>Industrial SI &gt; 19 kW</td>
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<tr>
<td>Recreational vehicles</td>
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<tr>
<td>--snowmobiles, motorcycles</td>
<td>800,000</td>
<td>September 2002</td>
</tr>
</tbody>
</table>
Summary - Changing Nonroad Contribution to Inventory

- These trends reflect programs finalized as of December 2000
- Rules on books provide some, but not enough control
- Nonroad diesel Phase 3 and “Pentathlon” rules will be critically important for the future
Contacts

- For additional information--
  - [www.epa.gov/otaq/nonroad.htm](http://www.epa.gov/otaq/nonroad.htm)
  - [www.epa.gov/otaq/nonrdmdl.htm](http://www.epa.gov/otaq/nonrdmdl.htm)

- For additional questions on--
  - Aircraft: [manning.bryan@epa.gov](mailto:manning.bryan@epa.gov)
  - Locomotives: [moulis.charles@epa.gov](mailto:moulis.charles@epa.gov)
  - Small SI: [carlson.philip@epa.gov](mailto:carlson.philip@epa.gov)
  - MARPOL: [revelt.jean-marie@epa.gov](mailto:revelt.jean-marie@epa.gov)
  - Marine diesel final rule: [stout.alan@epa.gov](mailto:stout.alan@epa.gov)
  - Recreational marine: [samulski.michael@epa.gov](mailto:samulski.michael@epa.gov)
  - Large SI: [stout.alan@epa.gov](mailto:stout.alan@epa.gov)
  - Recreational vehicles: [wehrly.linc@epa.gov](mailto:wehrly.linc@epa.gov)
  - Nonroad diesel: [jackson.cleophas@epa.gov](mailto:jackson.cleophas@epa.gov)