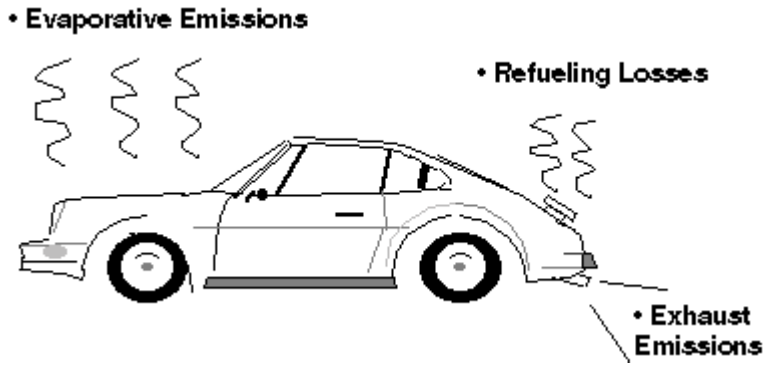
ME 410 Day 31

Emissions

- Major Types of Emissions and the Harm They Do
- How the Emissions Relate to Combustion
- Government Regulation of Emissions

Sources of Emissions



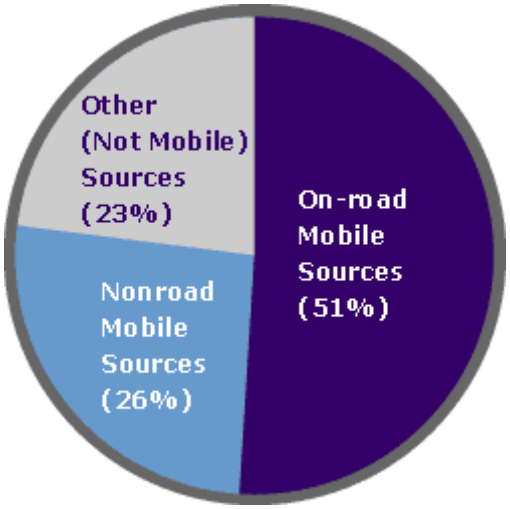
(Courtesy of the EPA webpage)

Emissions - Types

1. CO - carbon monoxide. Mostly SI
2. NO_x - oxides of nitrogen - NO and NO_2.
3. HC - unburned hydrocarbons
4. Particulates. Mostly CI

Harmful Effects

1. CO. This gas is harmful. It is produced by the following sources.

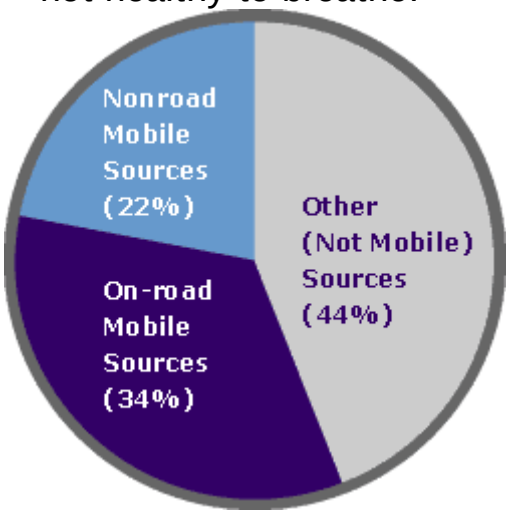


(EPA website - for 1999)

- The gas interferes with oxygenation of living organisms, i.e. their capacity to take in oxygen by breathing. It is especially harmful for people with heart disease and breathing disorders.

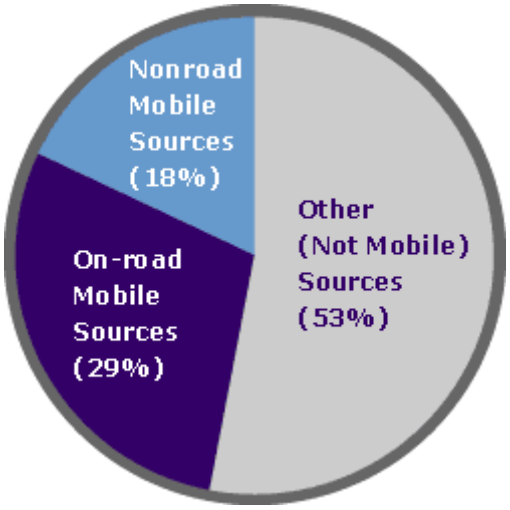
- More of a problem in the winter than in the summer.

2. NO_x. This stuff is not nice. It combines with unburned hydrocarbons in the presence of sunlight to produce ozone and smog. Ozone - not healthy to breathe.



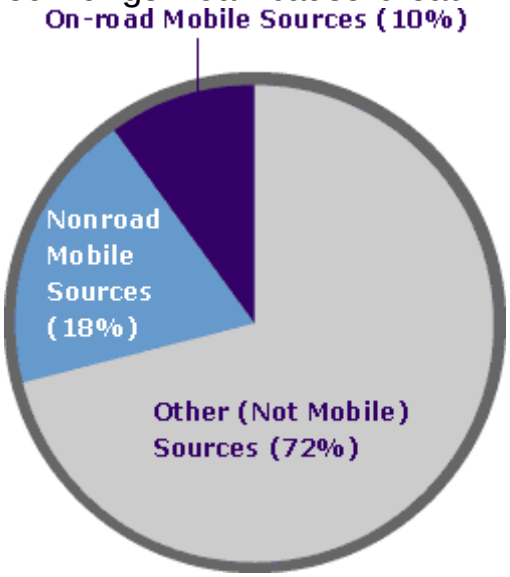
(EPA website - for 1999)

3. HC. This stuff is toxic, carcinogenic. Don't want to be breathing it. Plus it combines with NO_x to produce smog and ozone.



(EPA website - for 1999)

4. Particulates. Combustion generated soot to which adhere some organic compounds. Harmful ie toxic to humans, gets deposited in your lungs. Can cause breathing problems.



(EPA website - for 1999)

Many particulates are less than 2.5 NM in diameter, invisible. Consist of spheres of carbon to which are clinging organics. Some may be larger.

Hopefully you can see how important the IC engine is in the production of these undesirable substances.

Where do they come from?

SI Engines

1. CO.

We can get this from the basic combustion chemistry we know. Controlled primarily by fuel air equivalence ratio. Lean - not a problem. Rich, starts to appear, increases rapidly as mixture gets richer.

Oxygenating fuels - for example burning alcohol provides some extra O's.

2. NO_x.

The chemical reactions which form this take place at high temperature. These reactions are very temperature sensitive. Formation rate is an exponential function of temperature. So if we produce a high temperature in the burned gas, and there is a substantial amount of O_2 available, we will get NO_x. There is always plenty of N_2 available.

Peaks at $\phi = 0.9$. Lean mixture but still burning hot.

Other factors:

- EGR. Dilutes the mixture lowers burning temp. NOx goes down.
- Spark advance. By retarding the spark, burning temp goes down. NOx decreases.

3. Unburned Hydrocarbons

More properly called "organic" emissions. Large range of possible chemicals resulting from imperfections in the combustion process.

- Quenching of flame on walls
- Crevice

- Dissolution in oil on walls, then leave solution later in power stroke
- Blowby. Now mostly trapped and recycled.
- Very many complex mechanisms

Summary

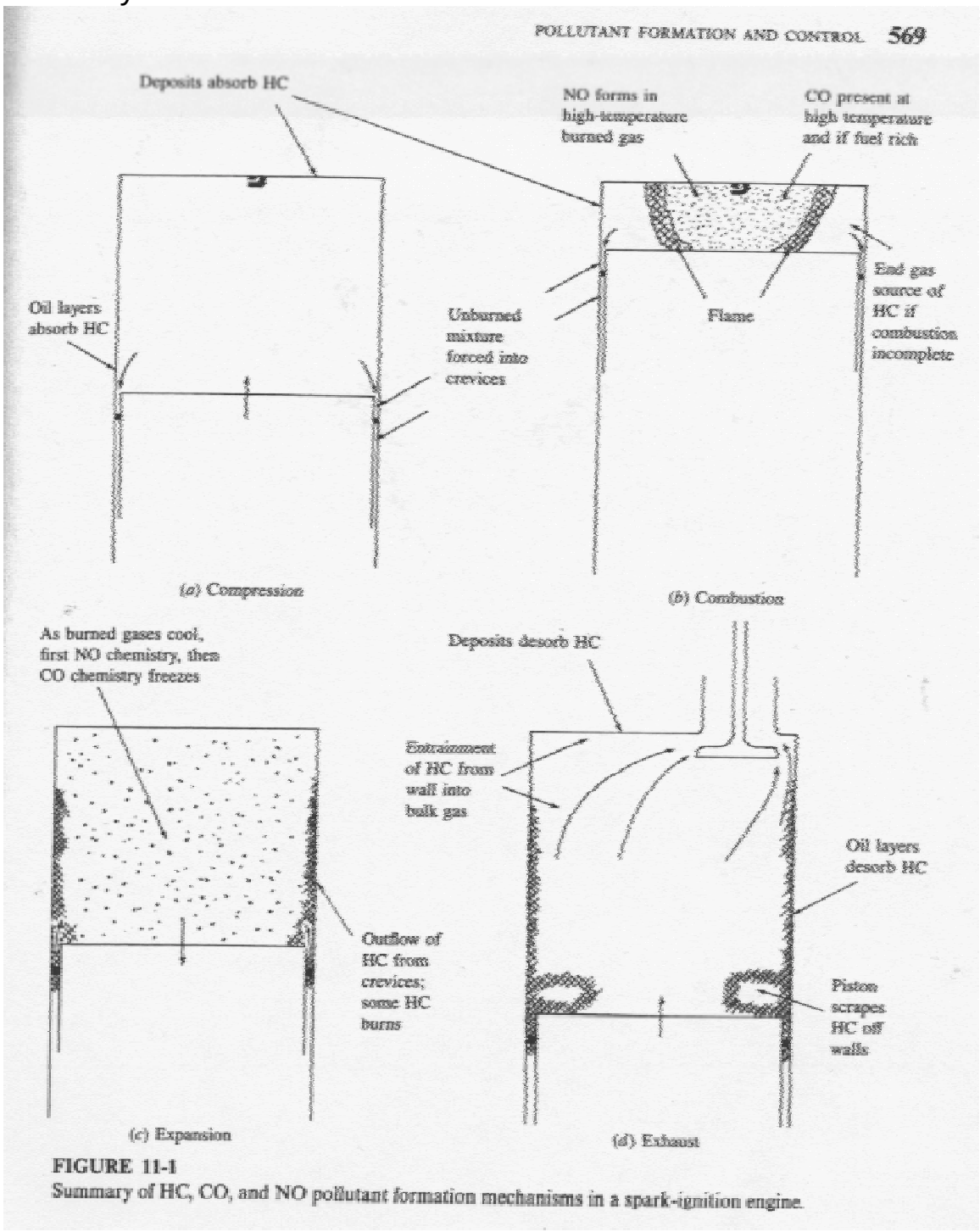


FIGURE 11-1
Summary of HC, CO, and NO pollutant formation mechanisms in a spark-ignition engine.

This is the problem area in evaporative emissions.

- Diurnal. Heat up in sun. Fuel evaporates.
- Running. Engine is hot. Fuel evaporates
- Hot soak. After running
- Refueling

CI Engines

1. CO. Not much of a problem.
2. NO_x.

Same mechanism as with SI. Since the engine runs lean, there is always plenty of extra O_2 around.

3. HC. Many mechanisms the same as SI. The fact that there is a higher molecular wt fuel makes more HC compounds possible.

4. Particulates. These are a very substantial problem with CI engines. The mechanism of

Summary

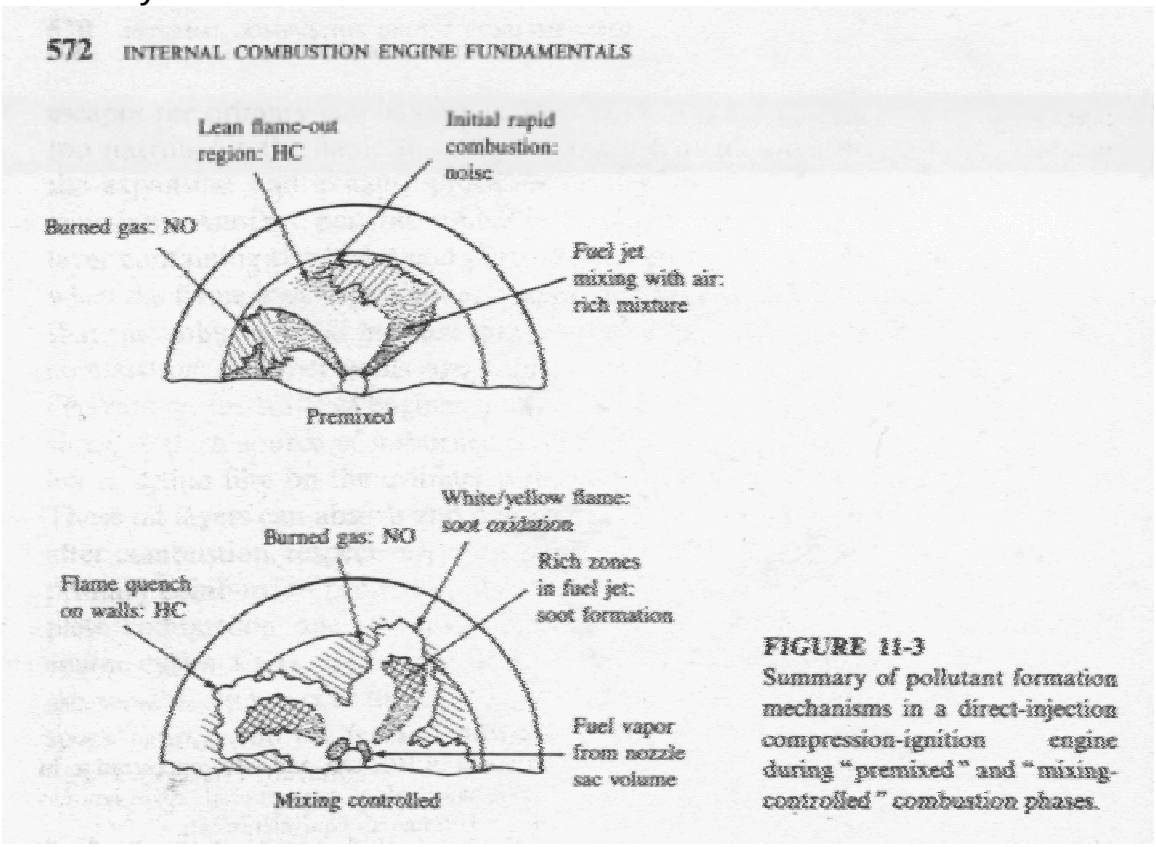


FIGURE 11-3
Summary of pollutant formation mechanisms in a direct-injection compression-ignition engine during "premixed" and "mixing-controlled" combustion phases.

Regulation of Emissions

The Clean Air Act of 1970 was the first major move by the United States towards a solution to the problem of emissions. The states and local governments were given authority to regulate non-mobile sources of emissions (e.g. power plants and factories) while the federal government took the authority over mobile sources.

The EPA is the federal agency responsible for the regulation. Its policies have been progressively more stringent over the years.

Current Regulations - Automobile and Light Trucks

Table 1
EPA Tier 1 Emission Standards for Passenger Cars and Light-Duty Trucks, FTP 75, g/mi

Category	50,000 miles/5 years						100,000 miles/10 years[1]					
	THC	NMHC	CO	NOx diesel	*NOx gasoline*	PM	THC	NMHC	CO	NOx diesel	*NOx gasoline*	PM
Passenger cars	0.41	0.25	3.4	1.0	*0.4*	0.08	-	0.31	4.2	1.25	*0.6*	0.10
LLDT, LVW <3,750 lbs	-	0.25	3.4	1.0	*0.4*	0.08	0.80	0.31	4.2	1.25	*0.6*	0.10
LLDT, LVW >3,750 lbs	-	0.32	4.4	-	*0.7*	0.08	0.80	0.40	5.5	0.97	*0.97*	0.10
HLDT, ALVW <5,750 lbs	0.32	-	4.4	-	*0.7*	-	0.80	0.46	6.4	0.98	*0.98*	0.10
HLDT, ALVW >5,750 lbs	0.39	-	5.0	-	*1.1*	-	0.80	0.56	7.3	1.53	*1.53*	0.12

1 - Useful life 120,000 miles/11 years for all HLDT standards and for THC standards for LDT

Abbreviations:
LVW - loaded vehicle weight (curb weight + 300 lbs)
ALVW - adjusted LVW (the numerical average of the curb weight and the GVWR)
LLDT - light light-duty truck (below 6,000 lbs GVWR)
HLDT - heavy light-duty truck (above 6,000 lbs GVWR)

(Source : www.dieselnet.com)

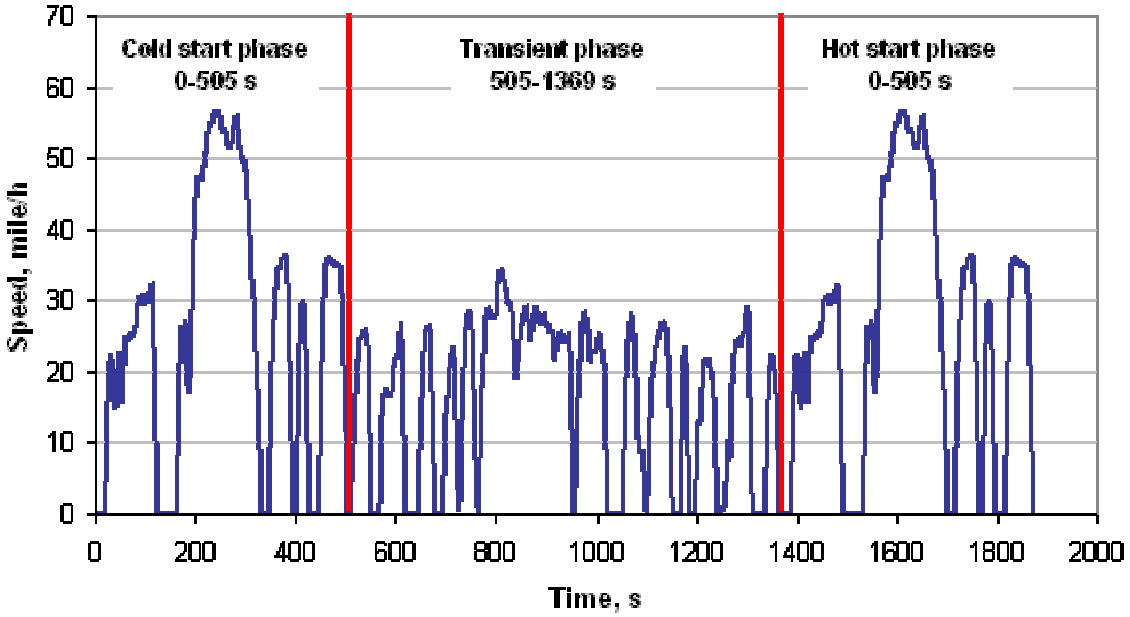
Please note: Units are g/mile.

The Tier 1 standards were mandated in the Clean Air Act of 1990. Phased in between 1994 and 1997.

How are the Measurements Made

FTP-75 Test

- Cold Start Phase
- Transient Phase
- Hot Start Phase



(Source: www.dieselnet.com)

Current Regulations - Heavy Duty Trucks and Buses

Table 1
EPA Emission Standards for Heavy-Duty Diesel Engines, g/bhp-hr

Year	HC	CO	NO_x	PM
Heavy-Duty Diesel Truck Engines				
1988	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1994	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10
Urban Bus Engines				
1991	1.3	15.5	5.0	0.25
1993	1.3	15.5	5.0	0.10
1994	1.3	15.5	5.0	0.07
1996	1.3	15.5	5.0	0.05*
1998	1.3	15.5	4.0	0.05*
* - in-use PM standard 0.07				

Source: www.dieselnet.com

Table 4
EPA Emission Standards for MY 2004 and Later HD Diesel Engines, g/bhp-hr

Option	$NMHC + NO_x$	NMHC
1	2.4	n/a
2	2.5	0.5

Consent Decree

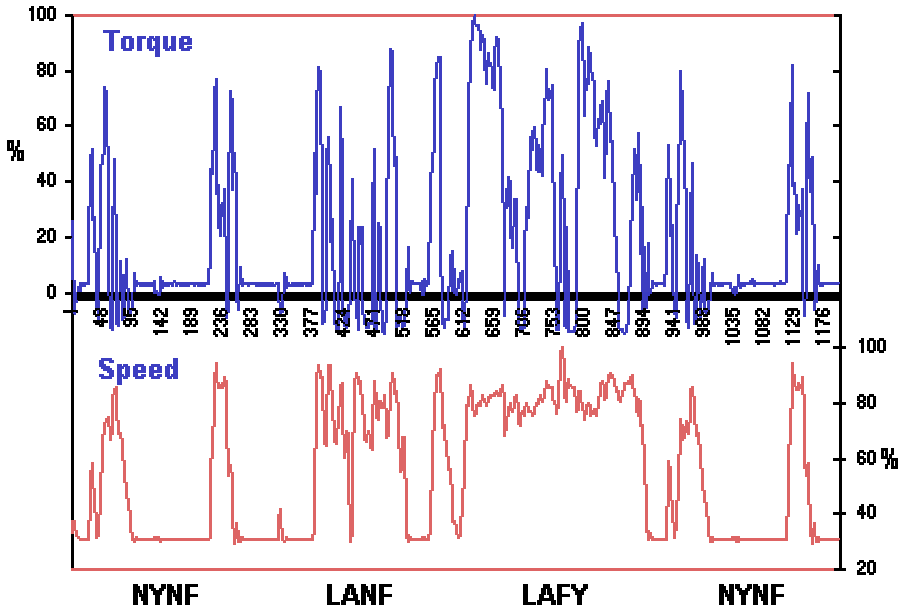
In October, 1998, a court settlement was reached between the EPA, Department of Justice, California ARB and engine manufacturers (Caterpillar, Cummins, Detroit Diesel, Volvo, Mack Trucks/Renault and Navistar) over the issue of high NO_x emissions from heavy-duty diesel engines during certa driving modes. Since the early 1990s, the manufacturers used engine control software that caused engines to switch to a more fuel-efficient (but higher NO_x) driving mode during steady highway cruising. The EPA considered this engine control strategy an illegal "emission defeat device".

Provisions of the Consent Decree included the following:

- Civil penalties for engine manufacturers and requirements to allocate funds for pollution research
- Upgrading existing engines to lower NO_x emissions
- Supplemental Emission Test (steady-state) with a limit equal to the FTP standard and NTE limits of 1.25 × FTP (with the exception of Navistar)
- Meeting the 2004 emission standards by October 2002, 15 months ahead of time

Testing.

On dynamometer. Chassis certification not usually required.



Source: Dieselnet

NYNF - light urban traffic frequent stops and starts.
LANF - heavy urban traffic infrequent stops and starts
LAFY - crowded LA freeway