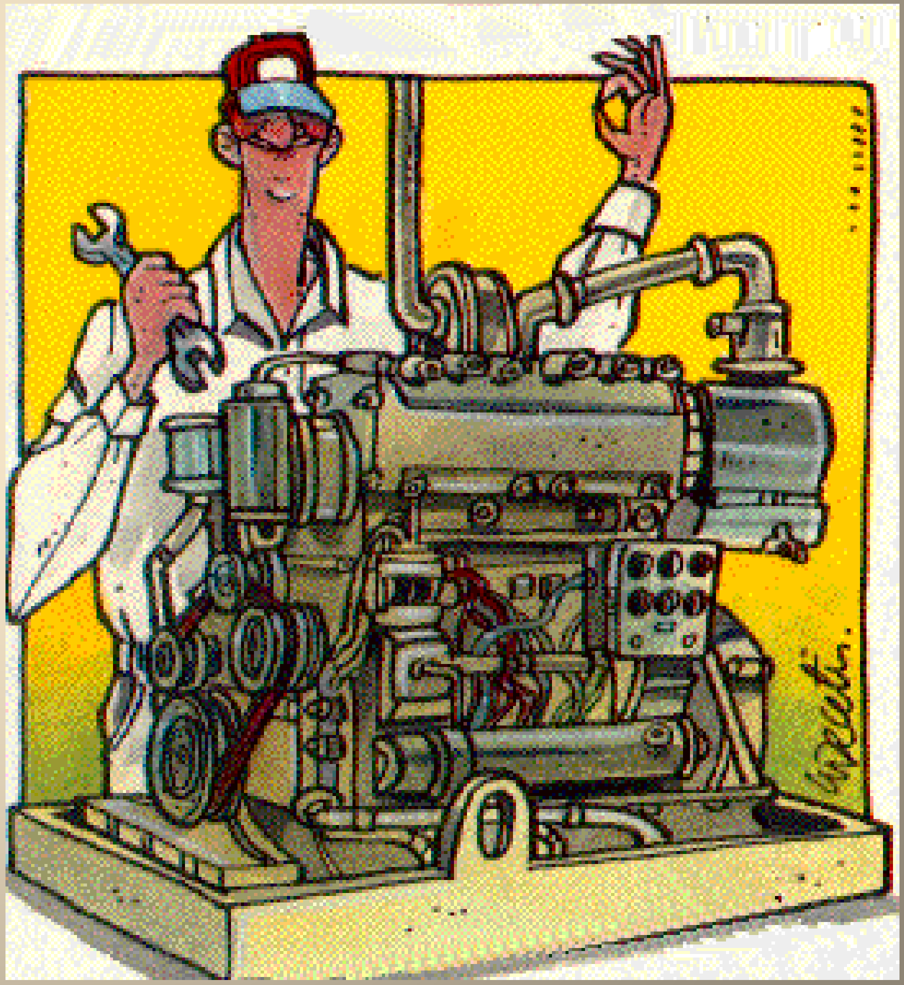
Stationary Reciprocating Engines

NACT 217

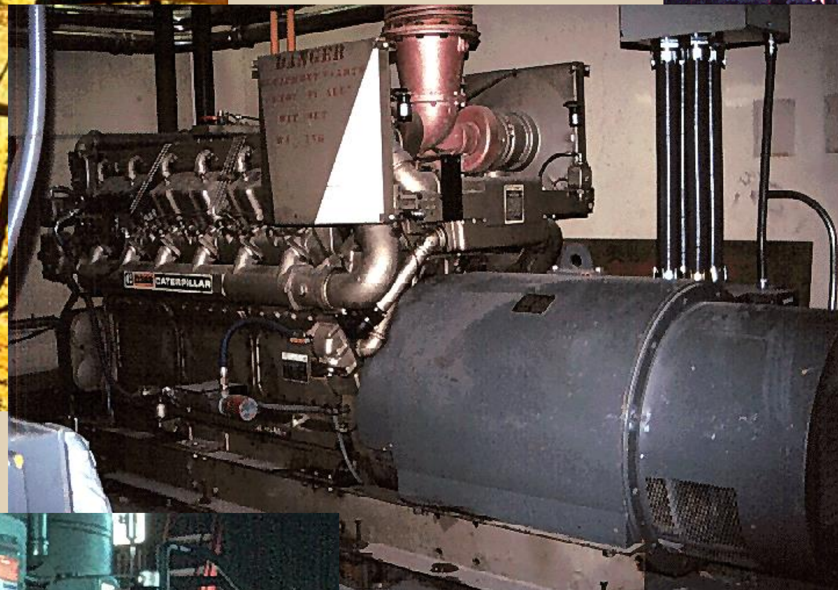


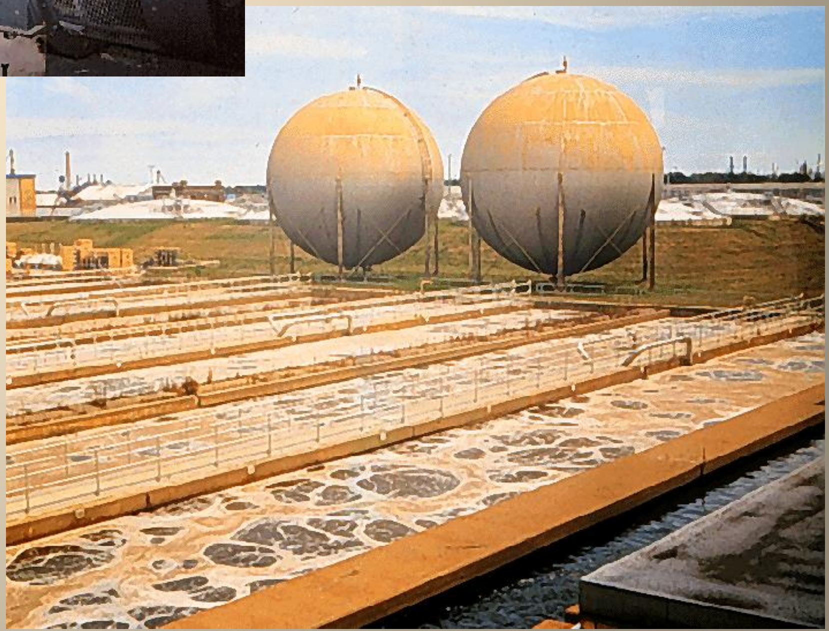
Short pre quiz

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

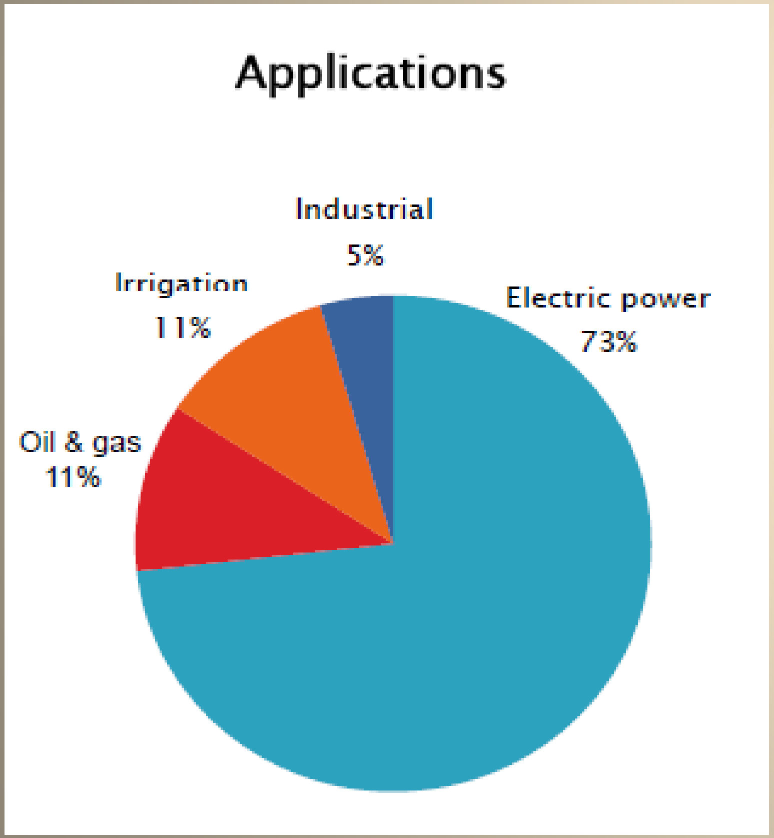
Course Overview

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


DANGER
CATERPILLAR



Stationary RICE at a Glance



- ~1.5 million stationary engines in the U.S.
  - 78% CI, 22% SI
  - ~900,000 used for emergency power
- Main HAPs emitted: formaldehyde, acetaldehyde, acrolein, methanol and PAH
- Main criteria pollutants emitted: Nox, CO, VOC, PM

Internal Combustion Generators by State 2006

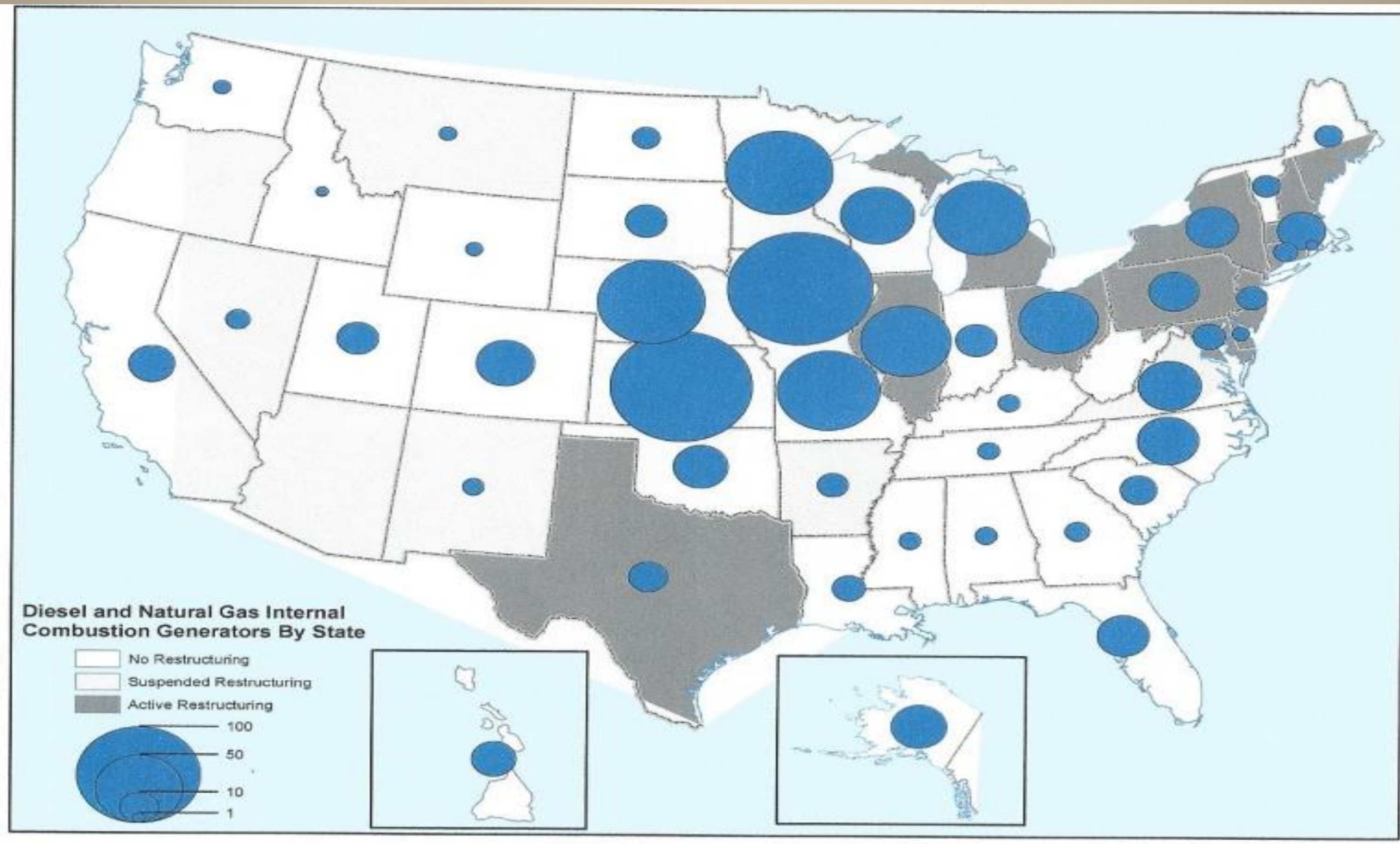


Figure 3-2. Internal Combustion Generators by State: 2006

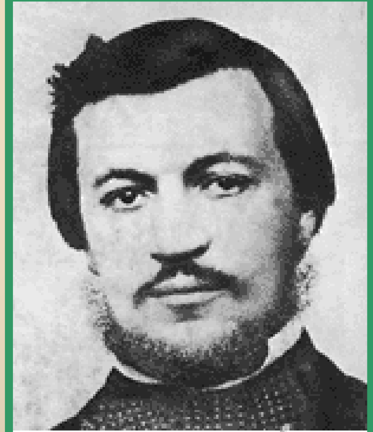
Source: U.S. Department of Energy, Energy Information Administration. 2007. "2006 EIA-906/920 Monthly Time Series."

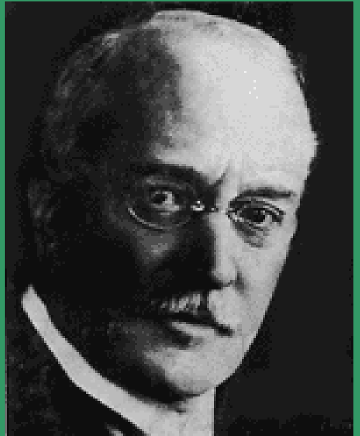
Fuels

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

History

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


Nikolaus August Otto
(1832 - 1891)


Rudolf Diesel
(1858 - 1913)

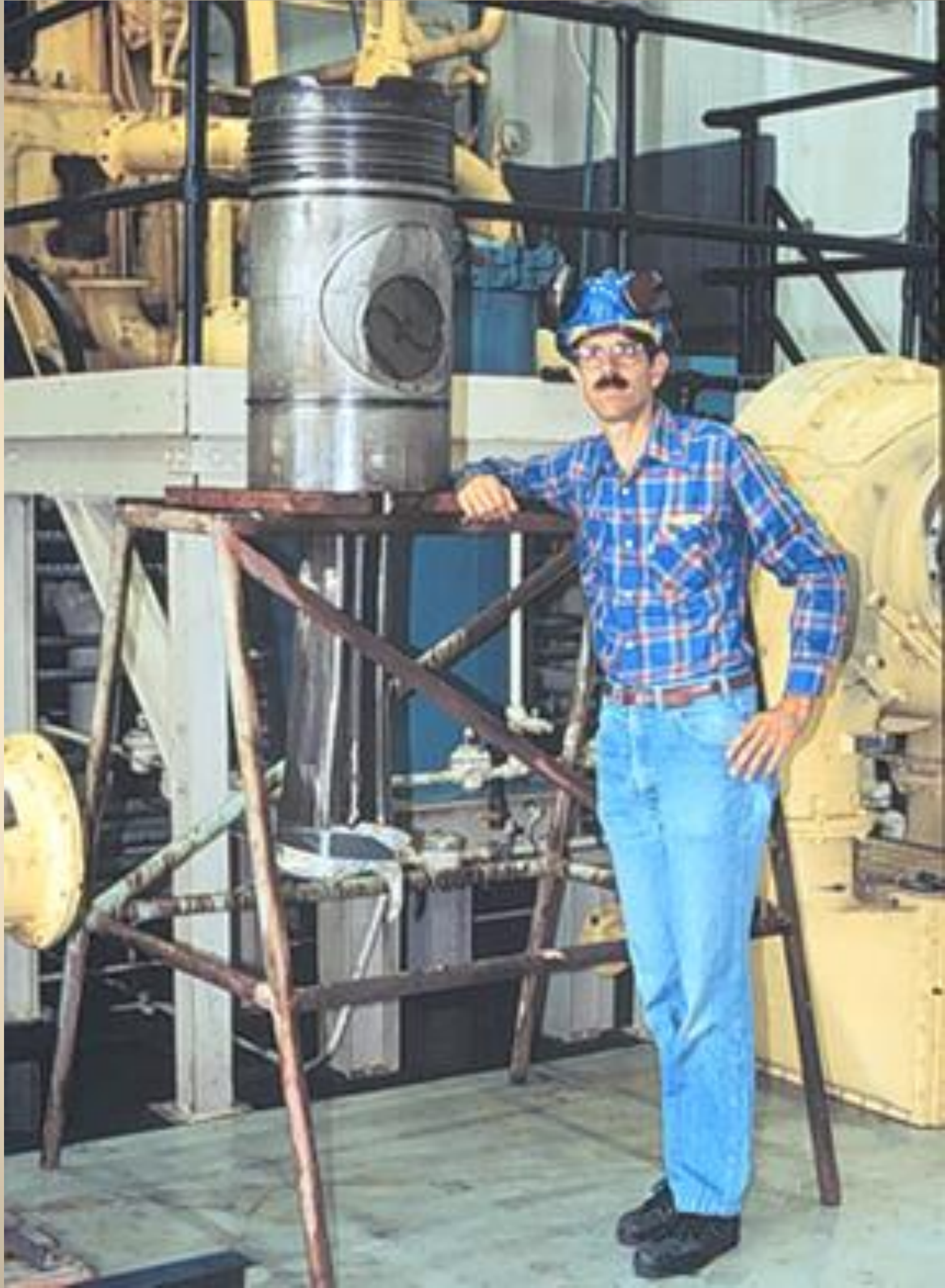
Types of Reciprocating Engines

Spark-Ignition (S-I) *or* Otto Cycle

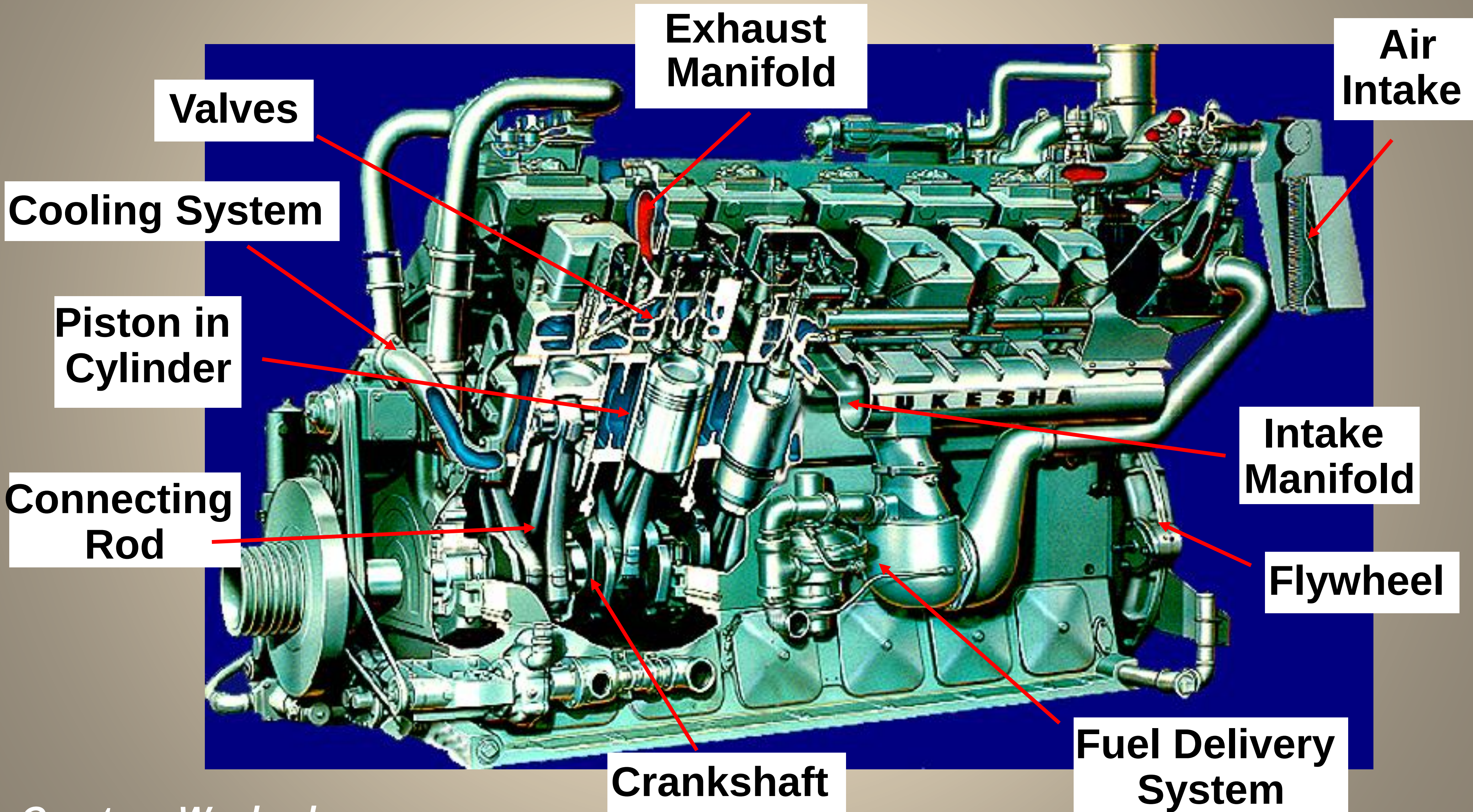
Compression-Ignition (C-I) *or* Diesel Cycle

Dual-Fuel (D-F)

Reciprocating Engine Operating Theory

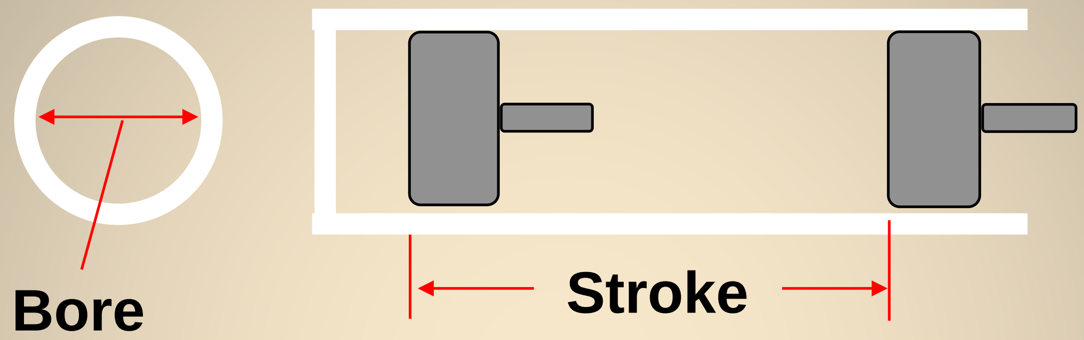


Reciprocating Engine



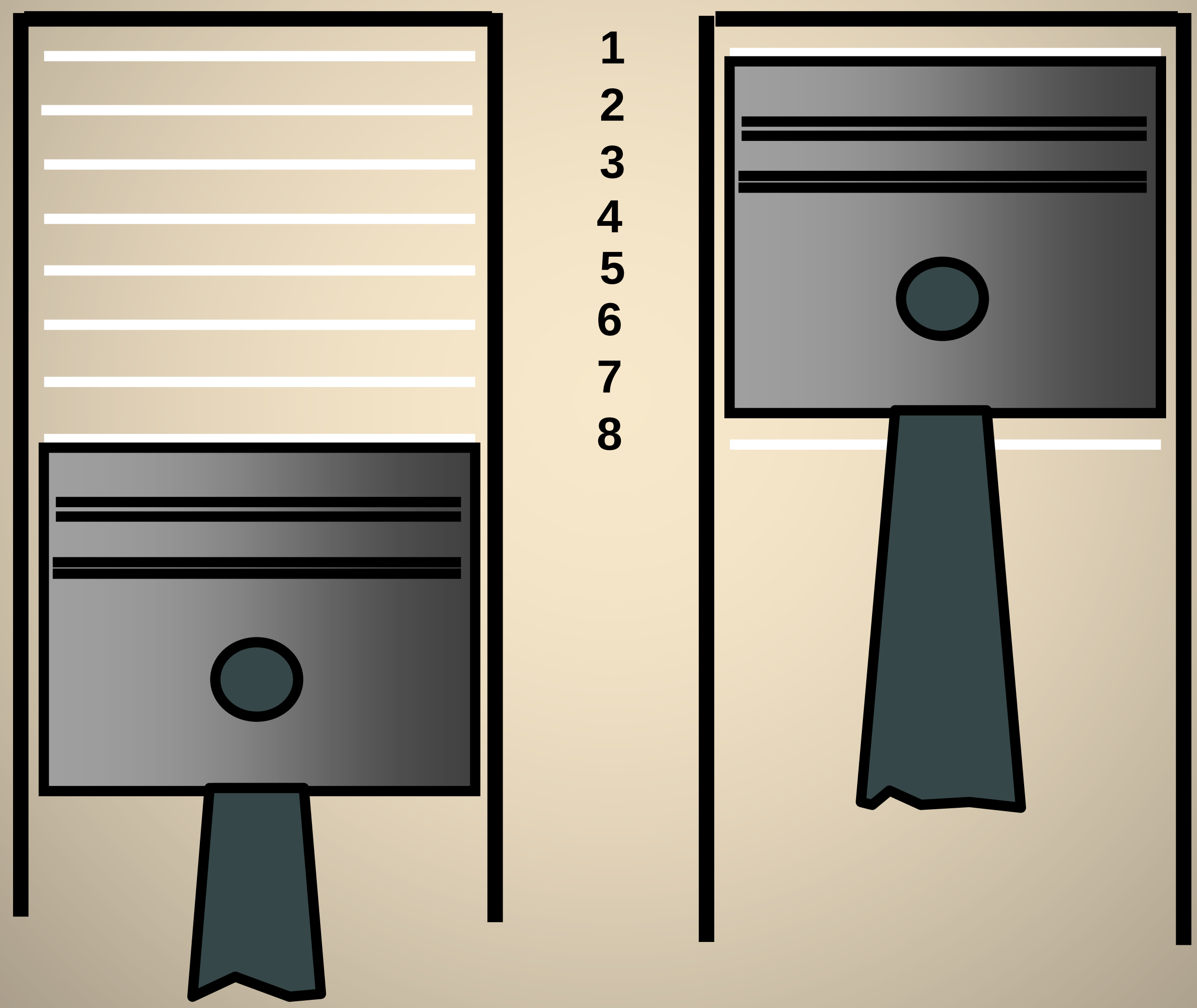
Courtesy Waukesha

Sizes

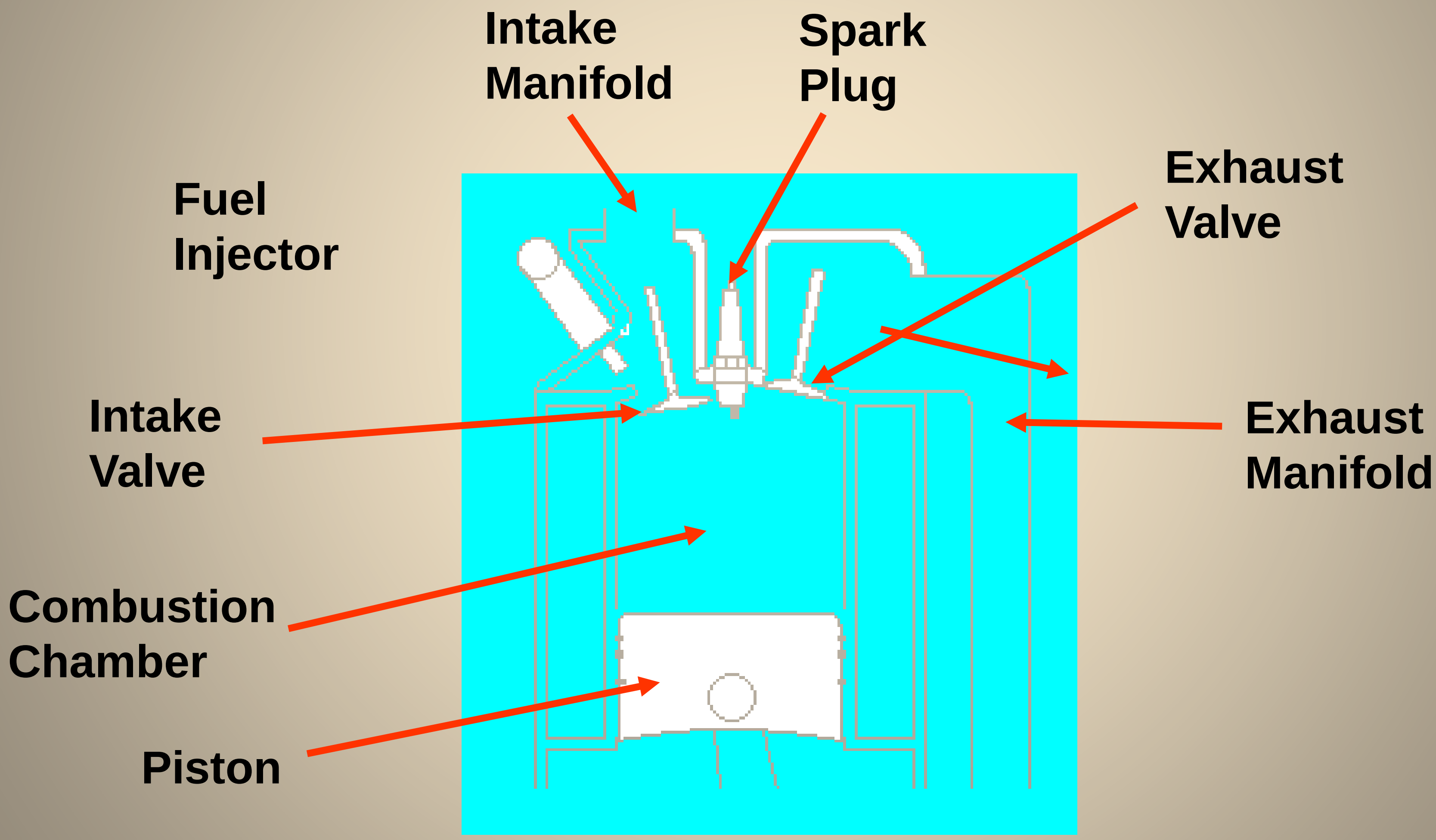


- Very small engines (1.0-3.0 in; 2-16 hp)
- Small bore (3.0-5.0 in; 3-50 hp)
- Medium bore (3.5-9.0 in; 50-1,200 hp)
- Large bore (8.0-18.0 in; 40-13,000 hp)

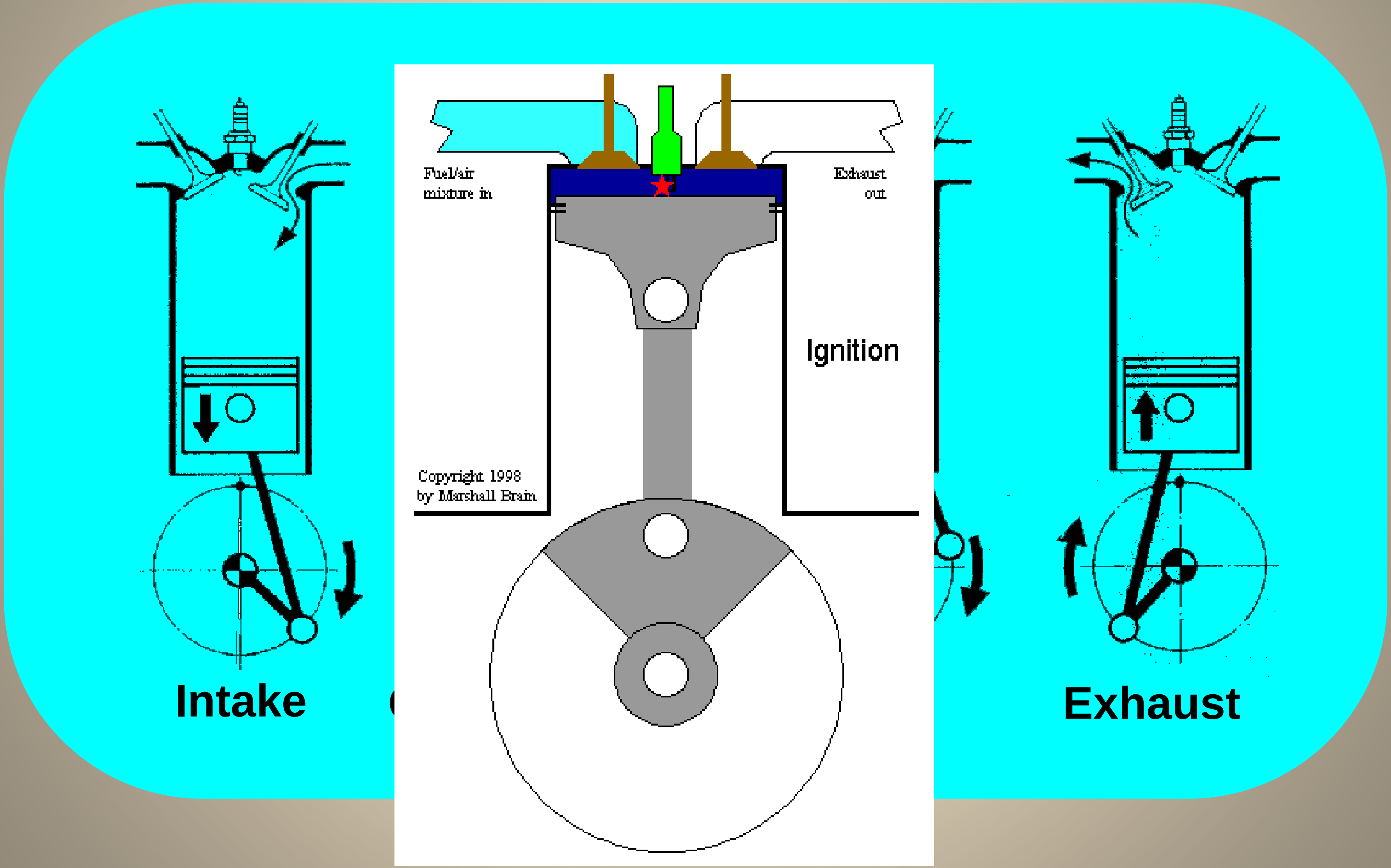
8:1 Compression Ratio



Cylinder and Related Components



Four-Stroke-Cycle Spark-Ignition Engine



Two Stroke Cycle Engine

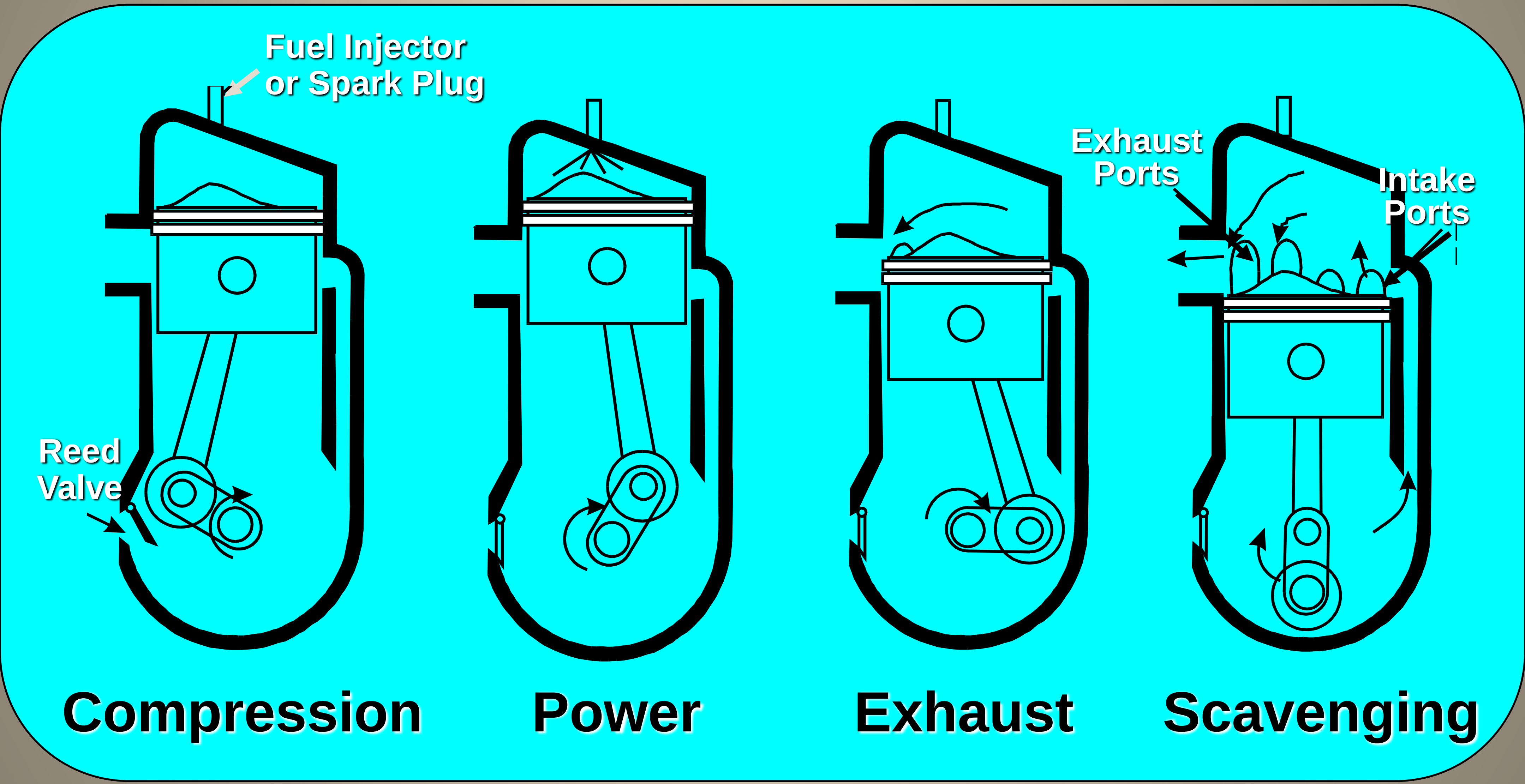
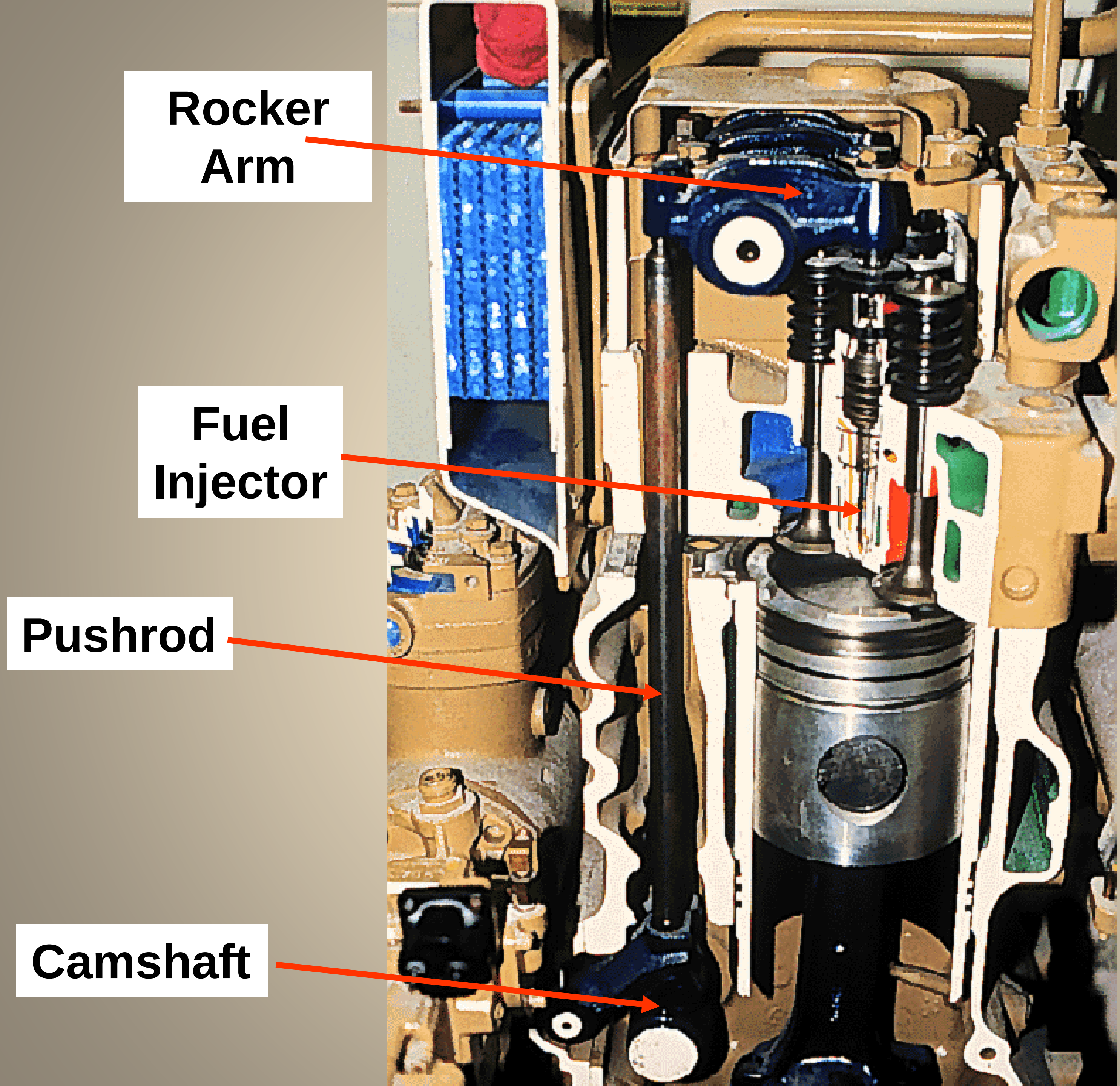
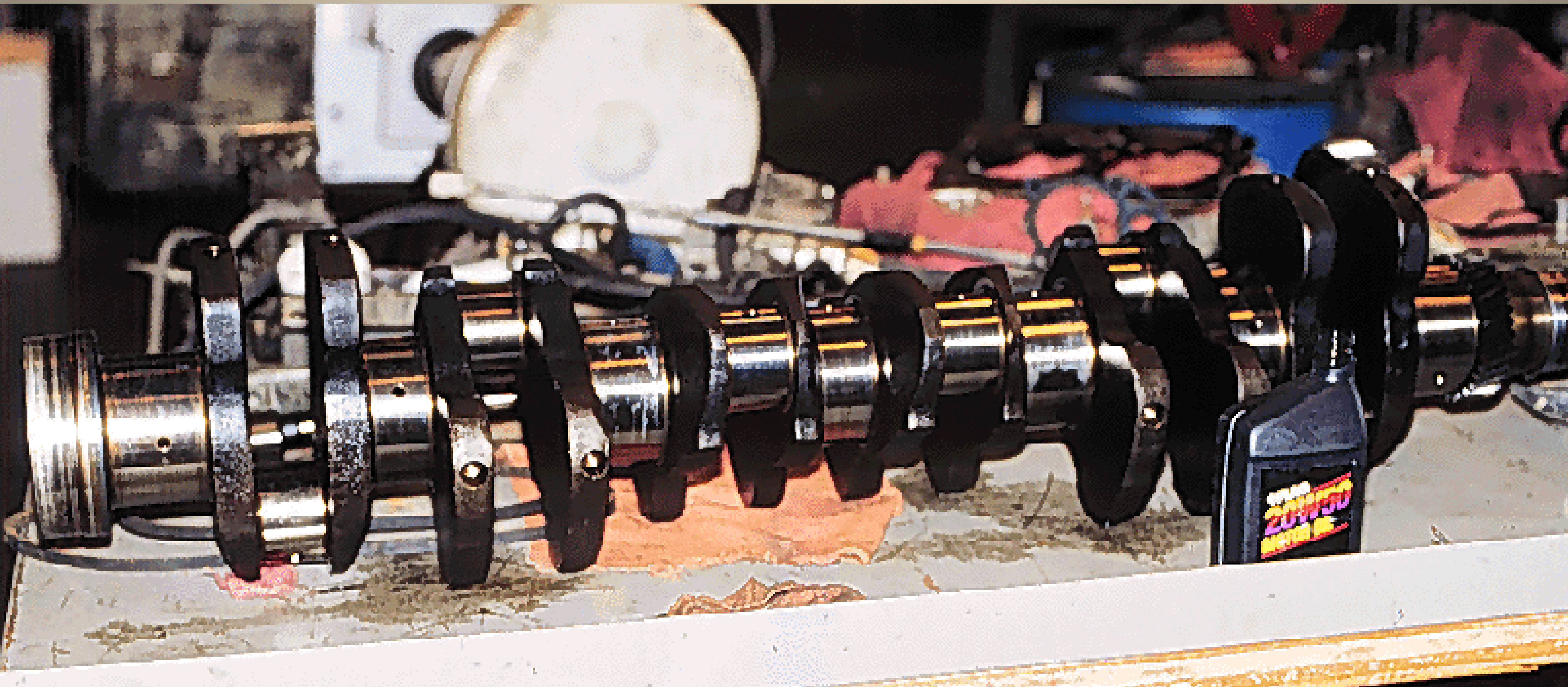


Figure 205.5

Diesel Engine Cross-Section



Crankshaft



Energy Conversions

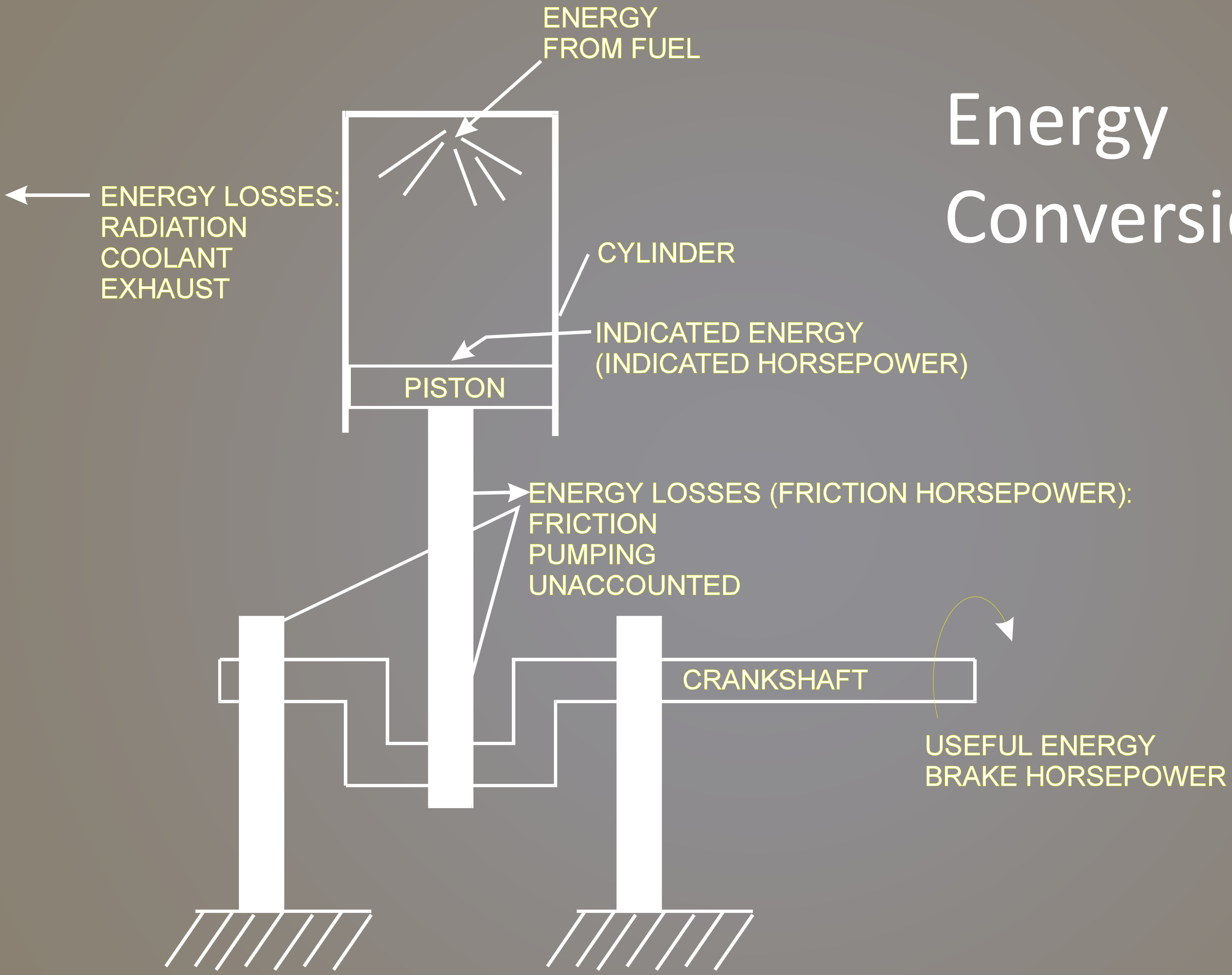


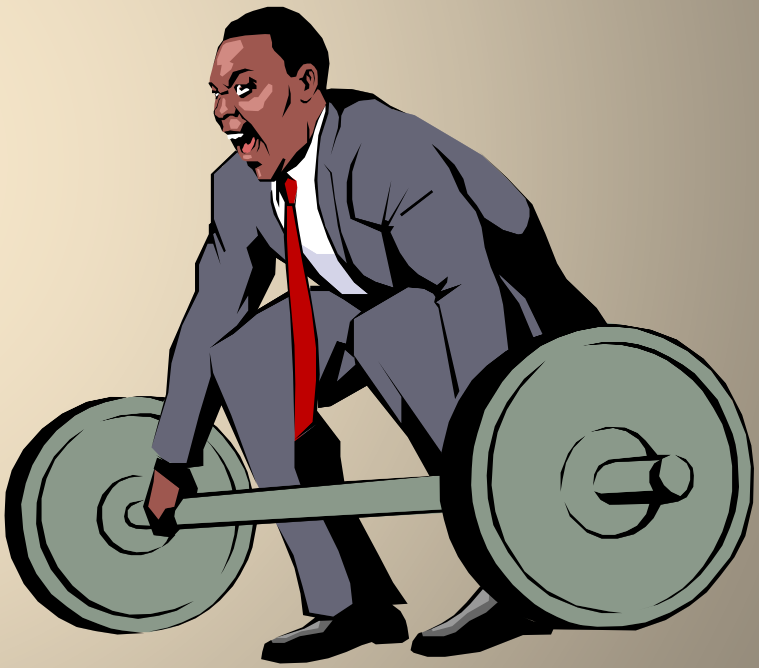
Figure 206.1

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



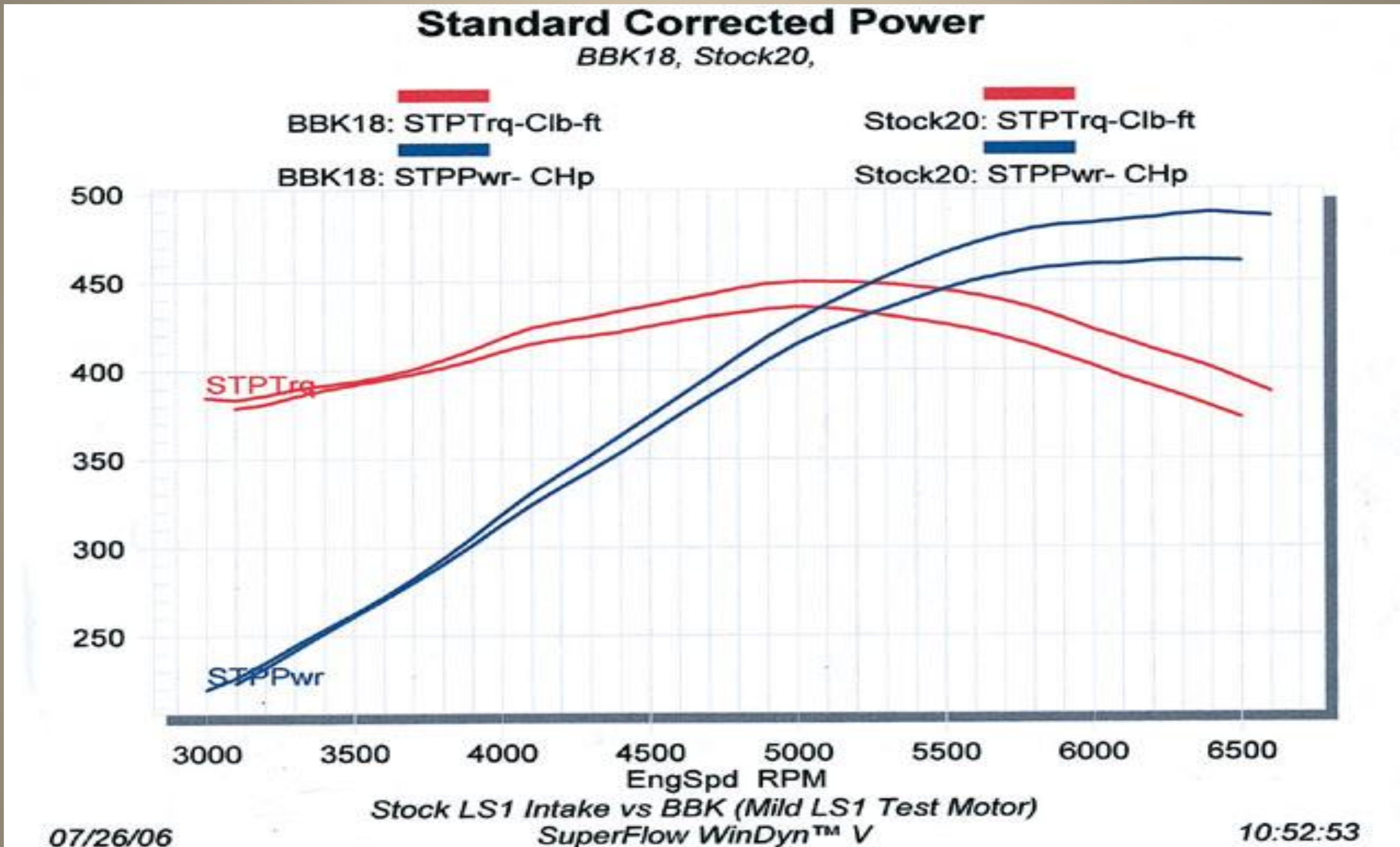
Ways to Determine Horsepower

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

Fuel Consumption

$$HP = \frac{\text{Torque (ft-lbs)} \times \text{RPM}}{5252}$$

Engine Torque


Standard Corrected Power
BBK18, Stock20,
BBK18: STPTrq-Clb-ft
BBK18: STPPwr- CHp
Stock20: STPTrq-Clb-ft
Stock20: STPPwr- CHp
500
450
400
350
300
250
STPTrq
STPPwr
3000
3500
4000
4500
5000
5500
6000
6500
EngSpd RPM
Stock LS1 Intake vs BBK (Mild LS1 Test Motor)
SuperFlow WinDyn™ V
07/26/06
10:52:53

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

Carburetor System

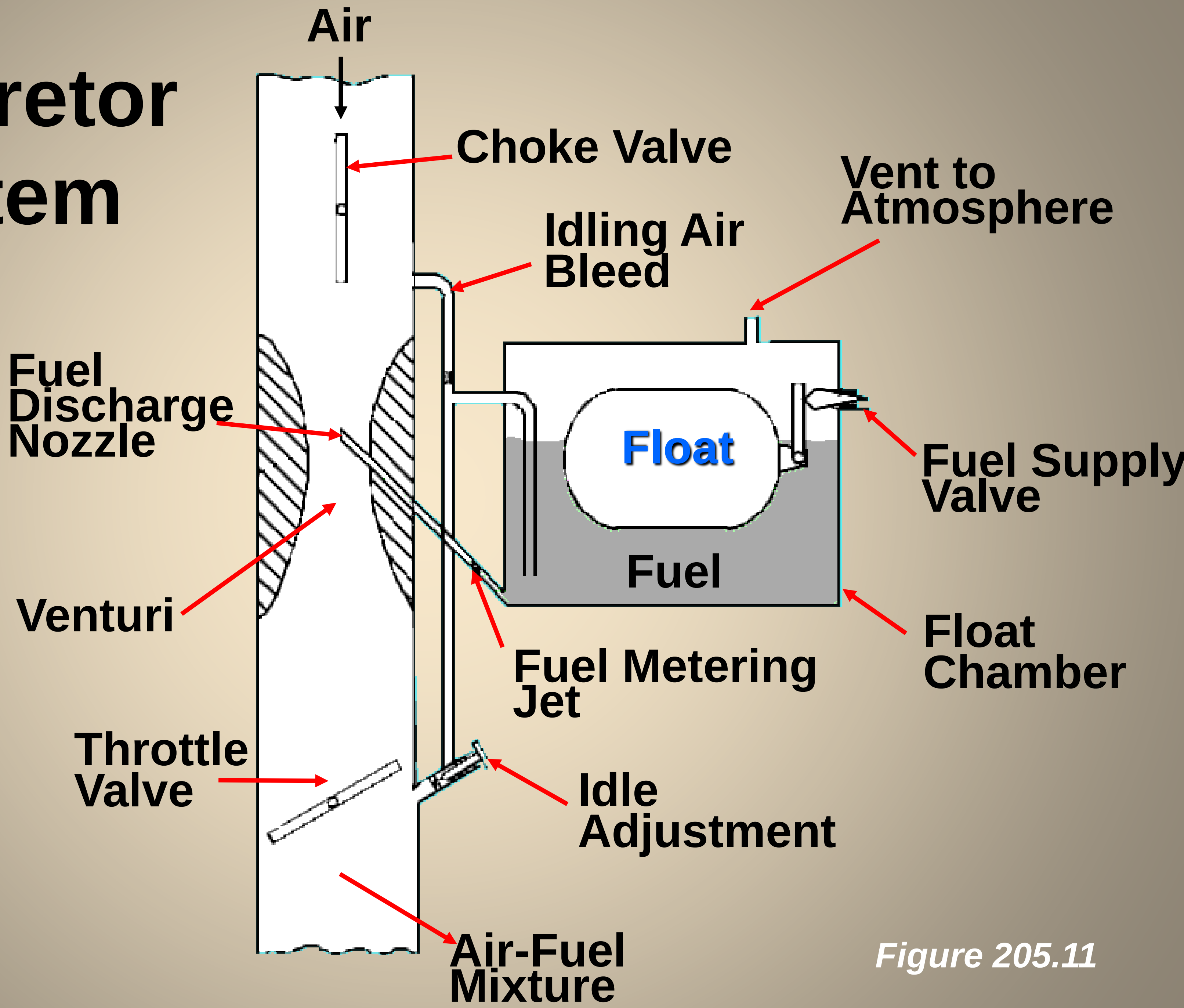
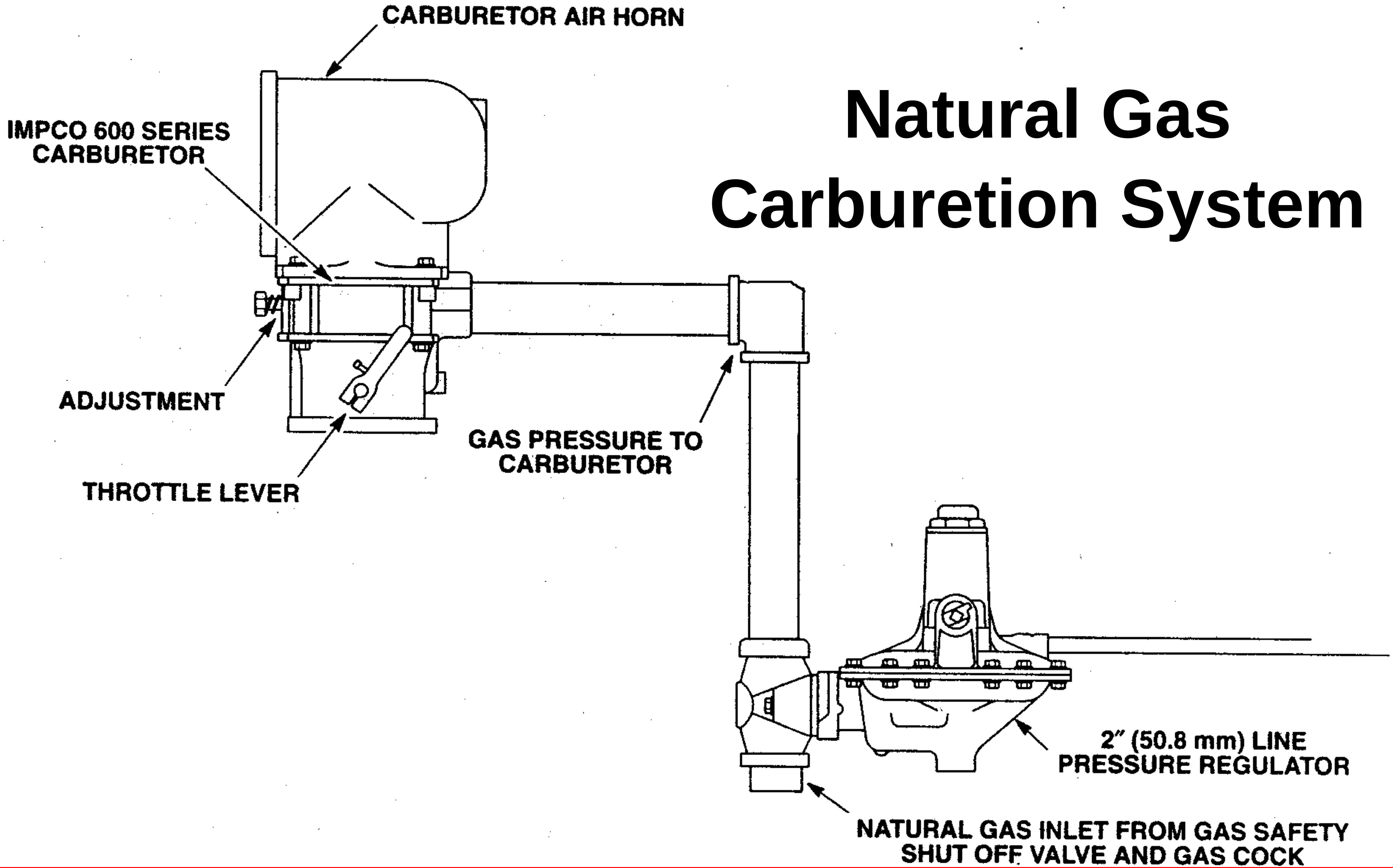
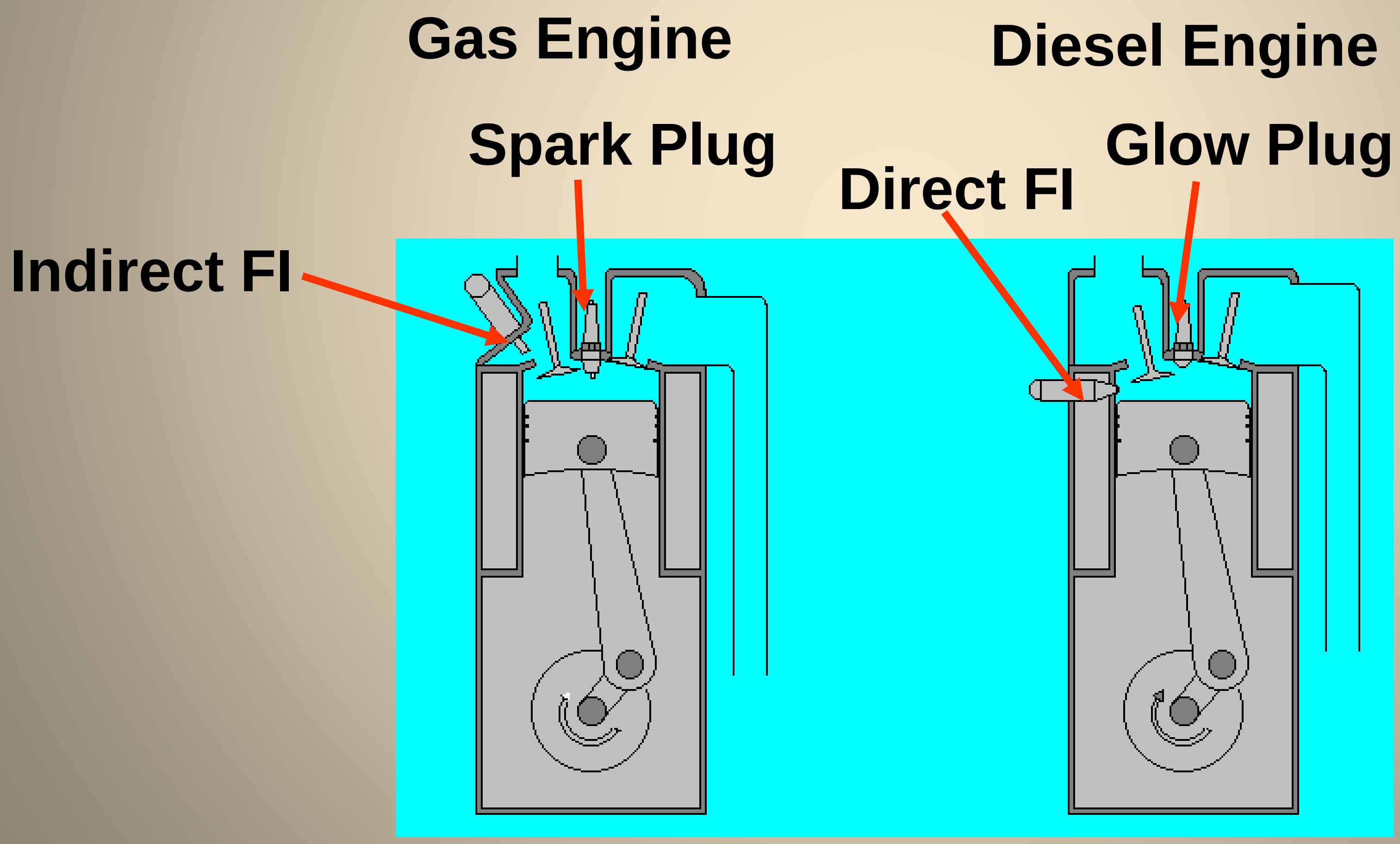


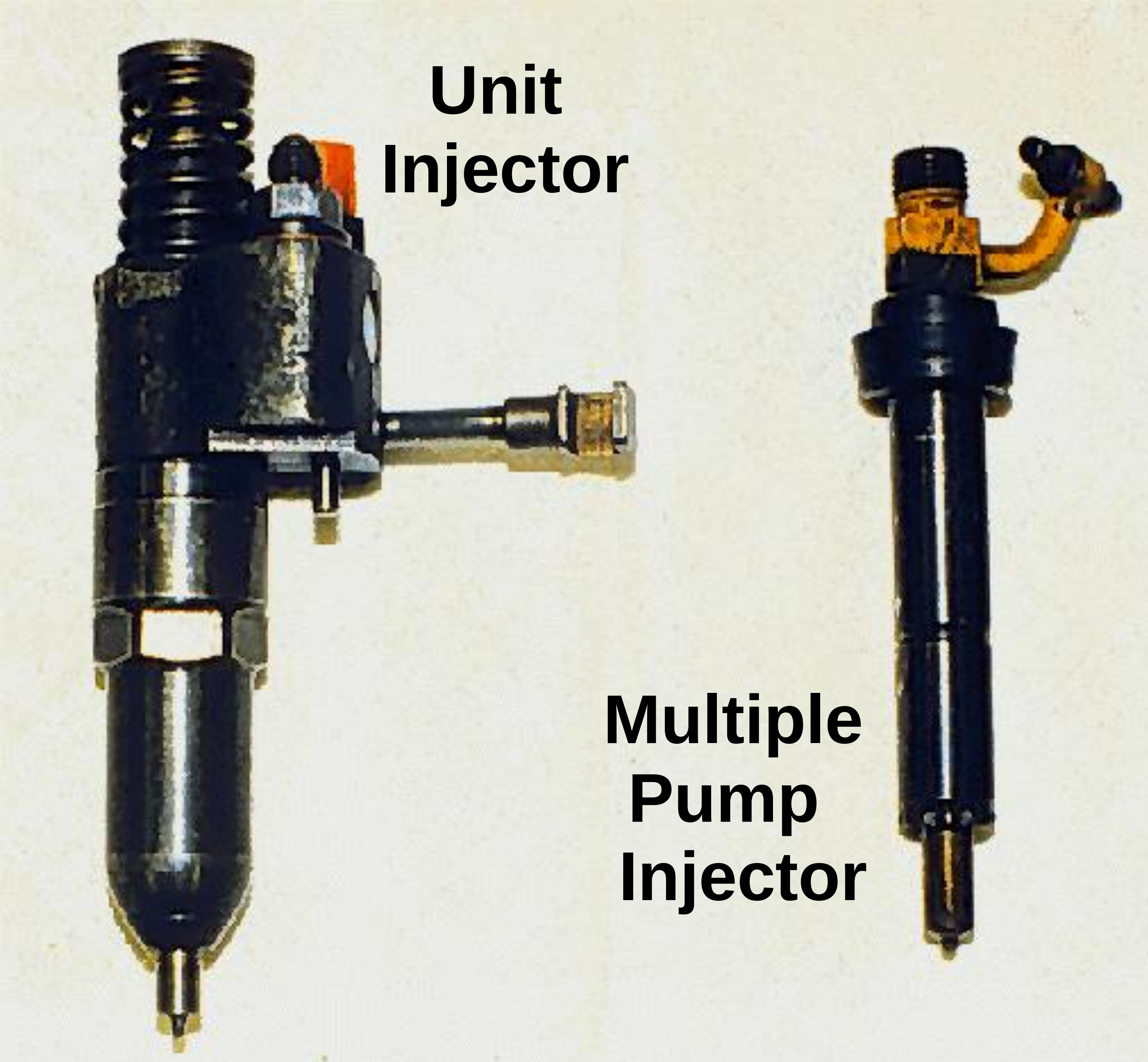
Figure 205.11

Natural Gas Carburetion System

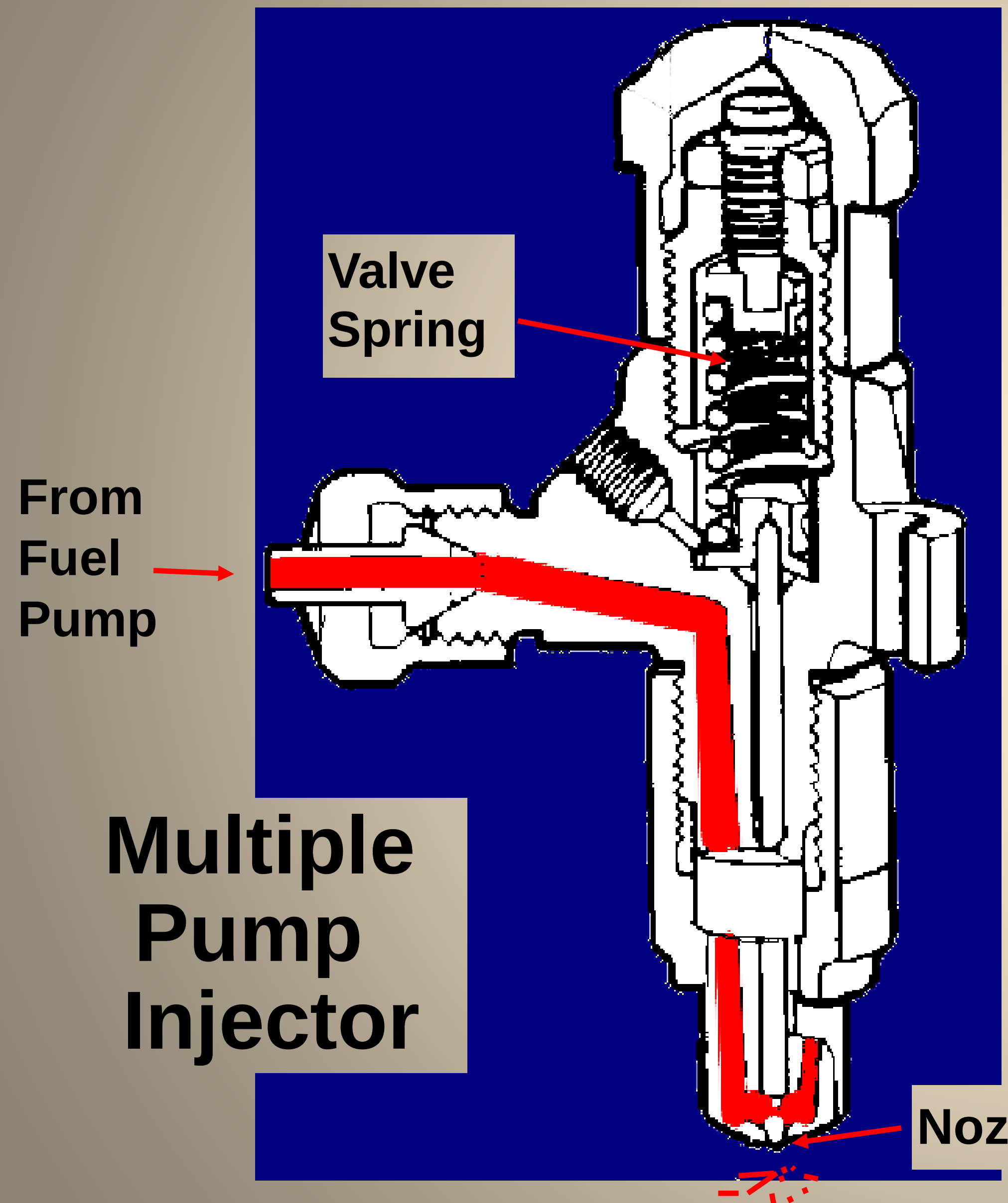


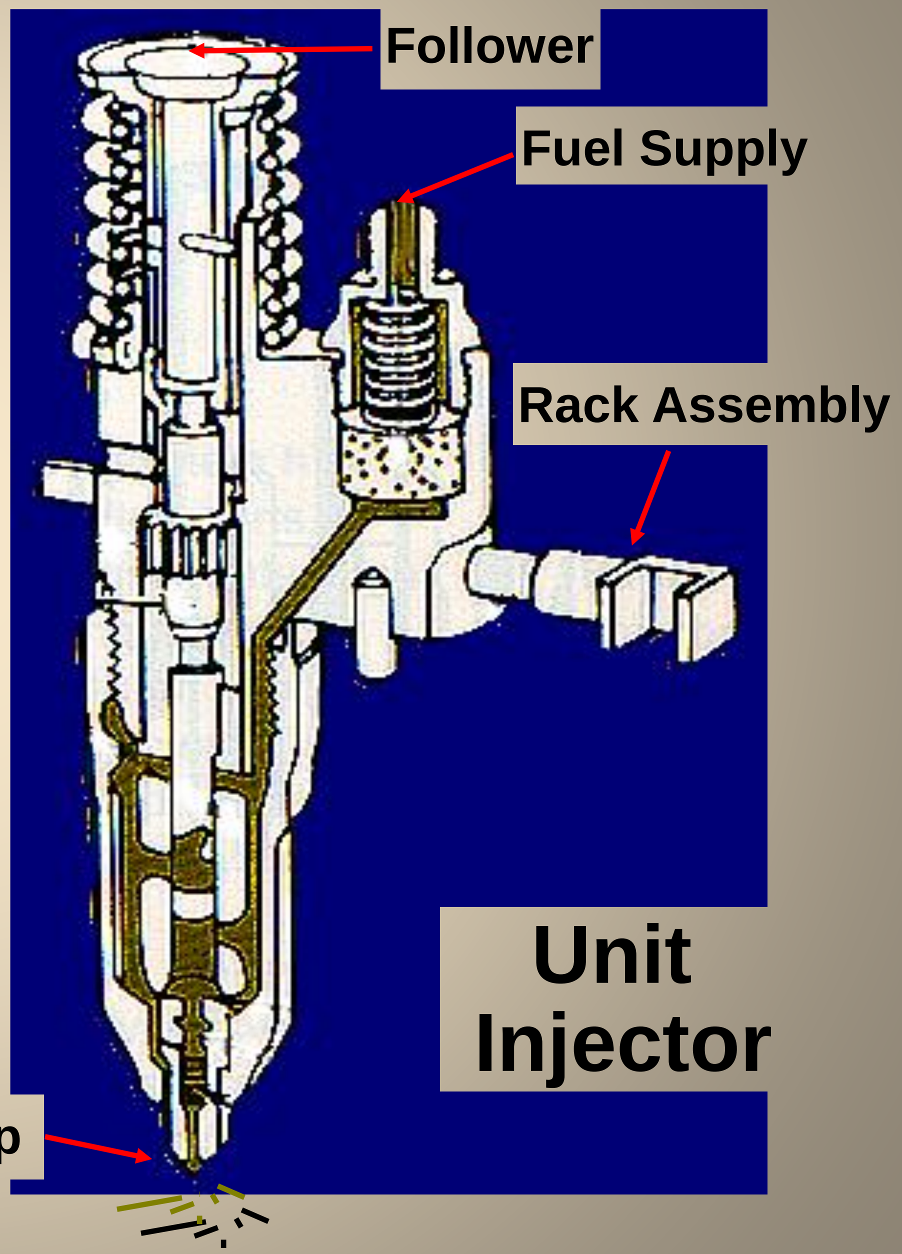
Models of Fuel Injection



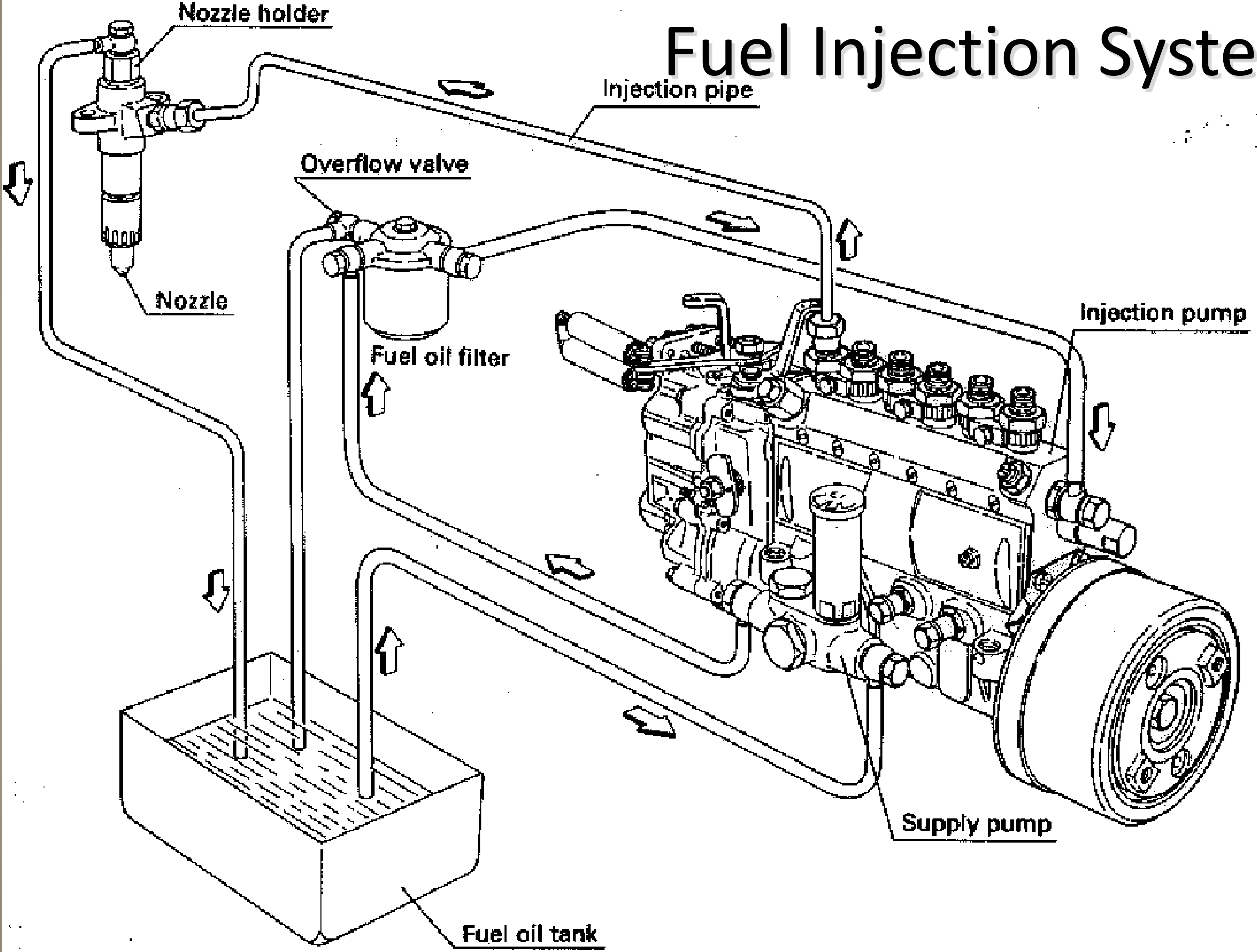

Unit Injector
Multiple Pump Injector

Fuel Injectors



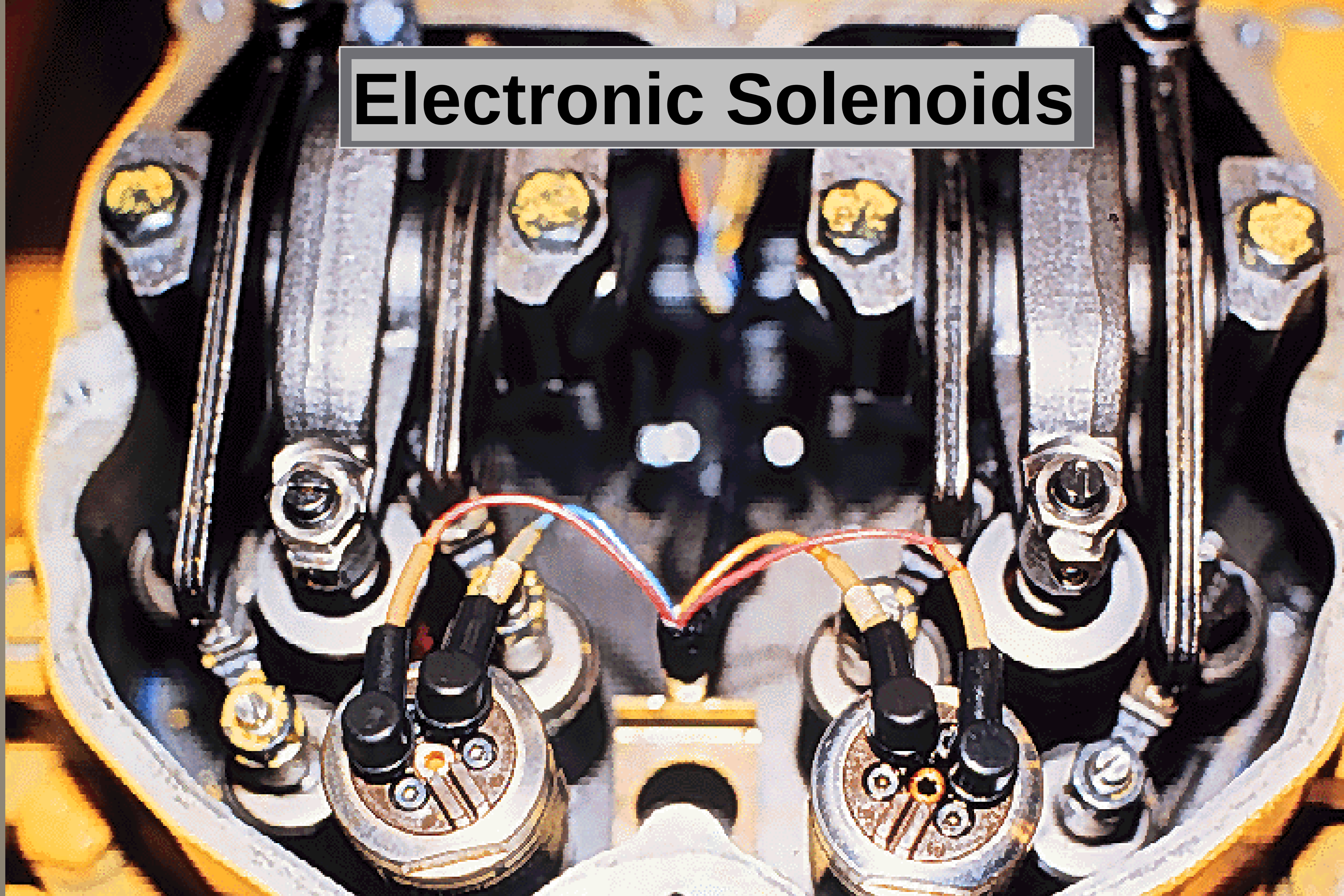


Fuel Injection System



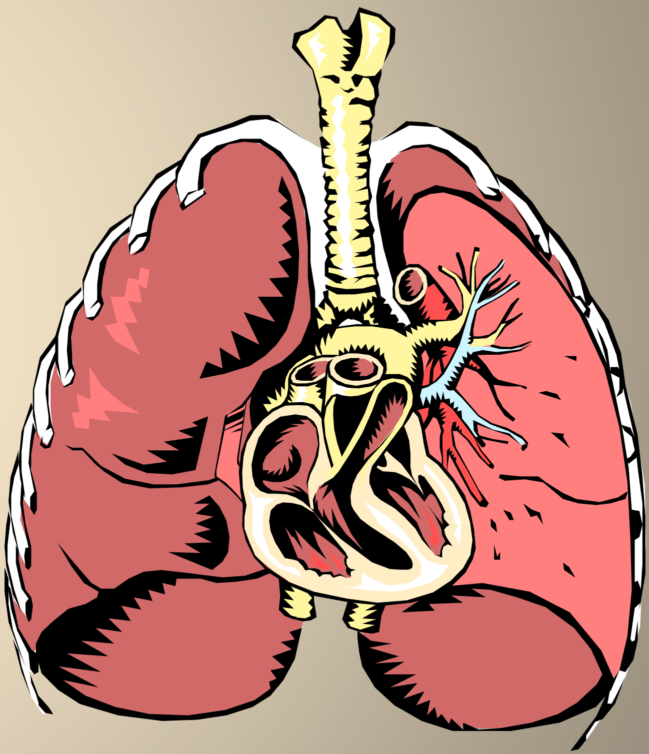
Fuel Injection Lines

Electronic Solenoids

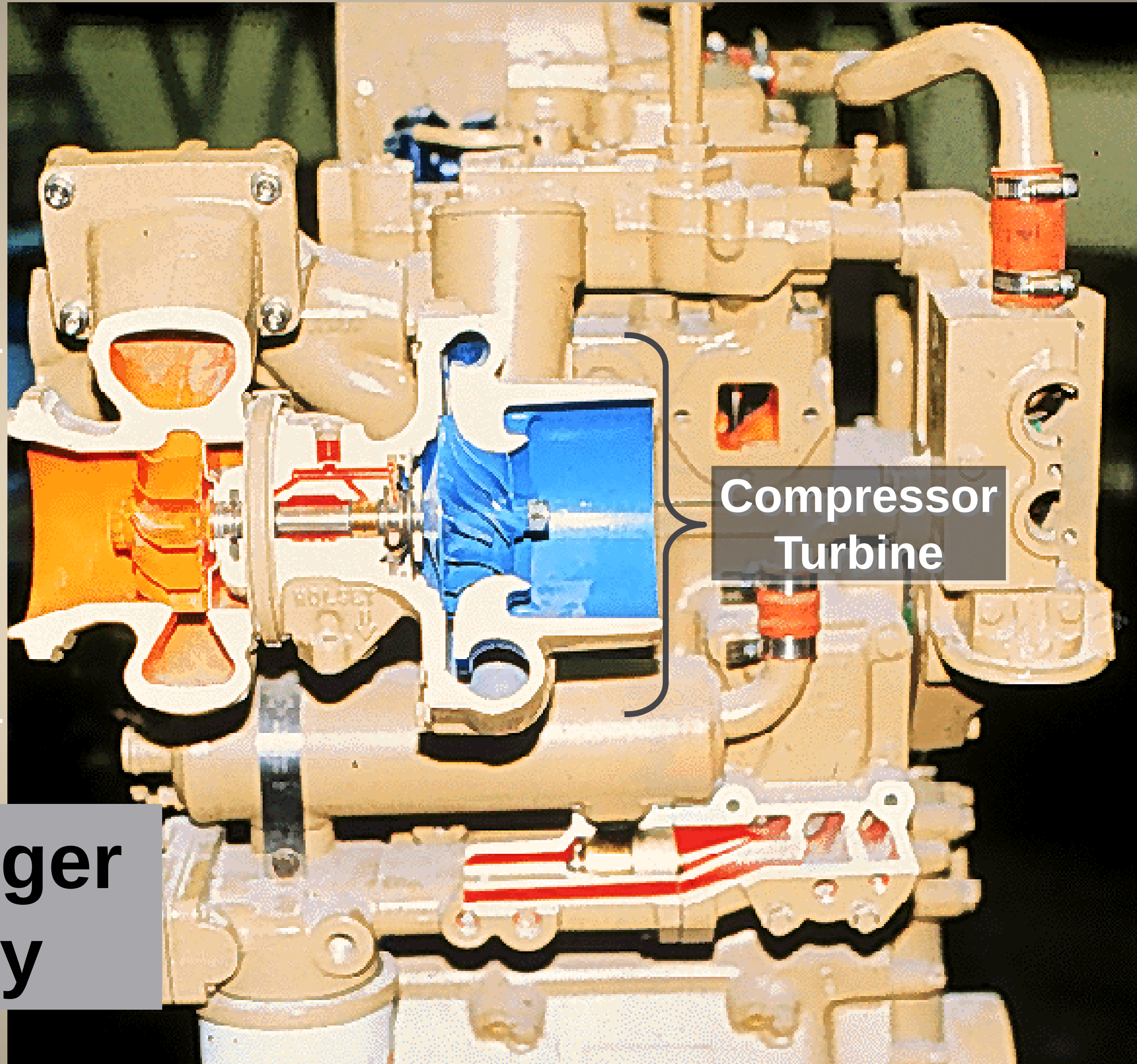


Increasing Air Intake

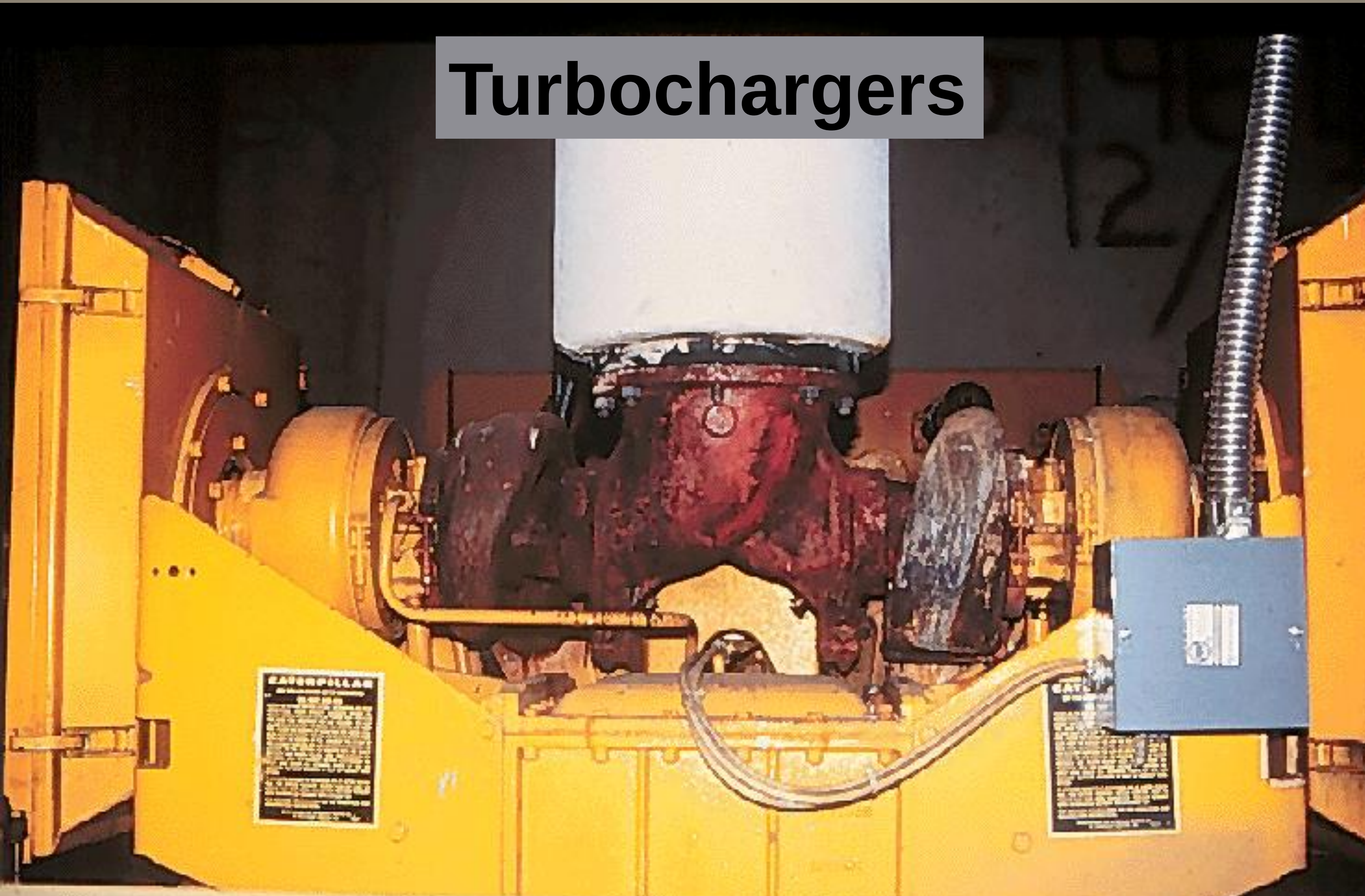
- Turbochargers
- Superchargers
- Blower-Scavenging



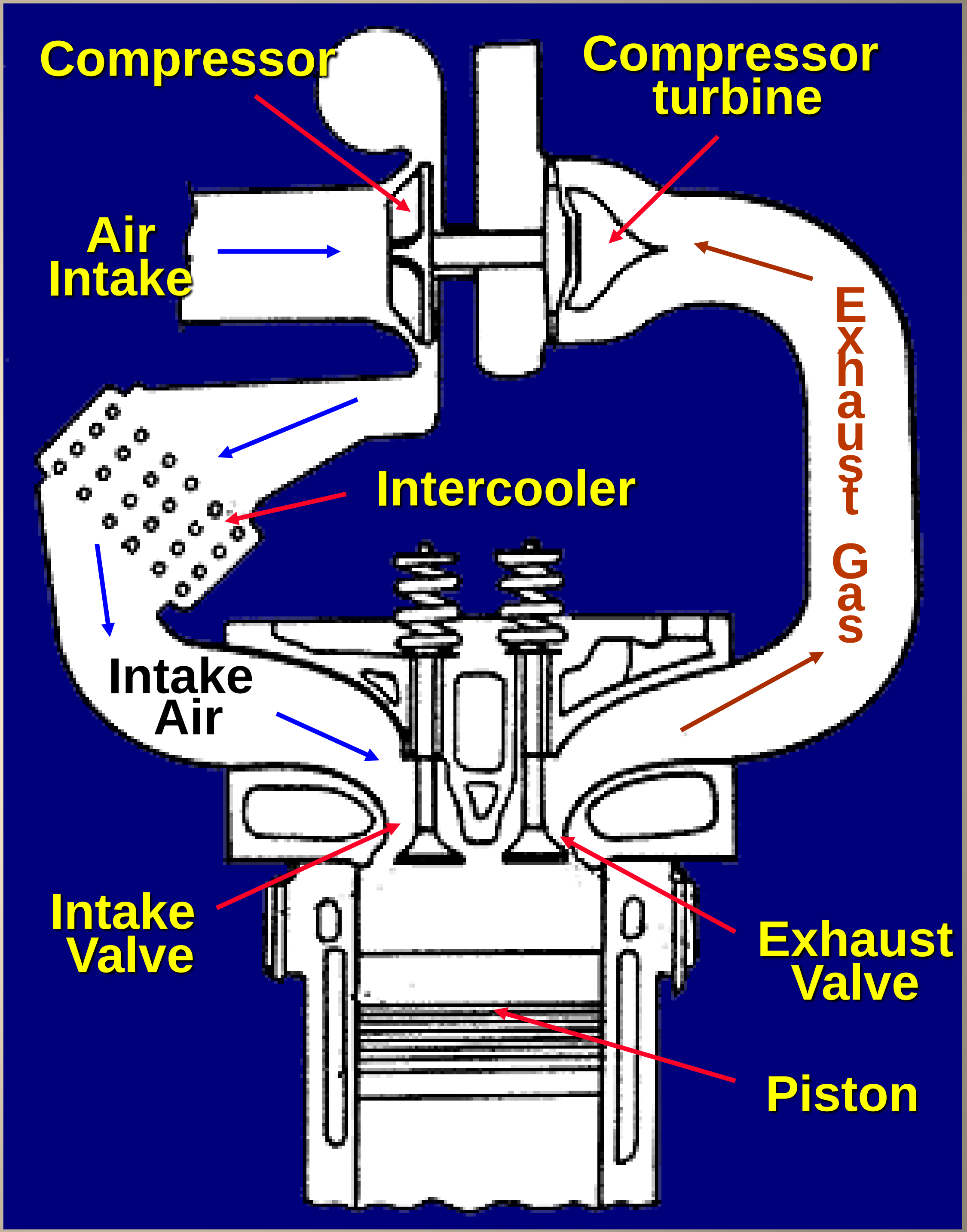
Turbocharger Cutaway



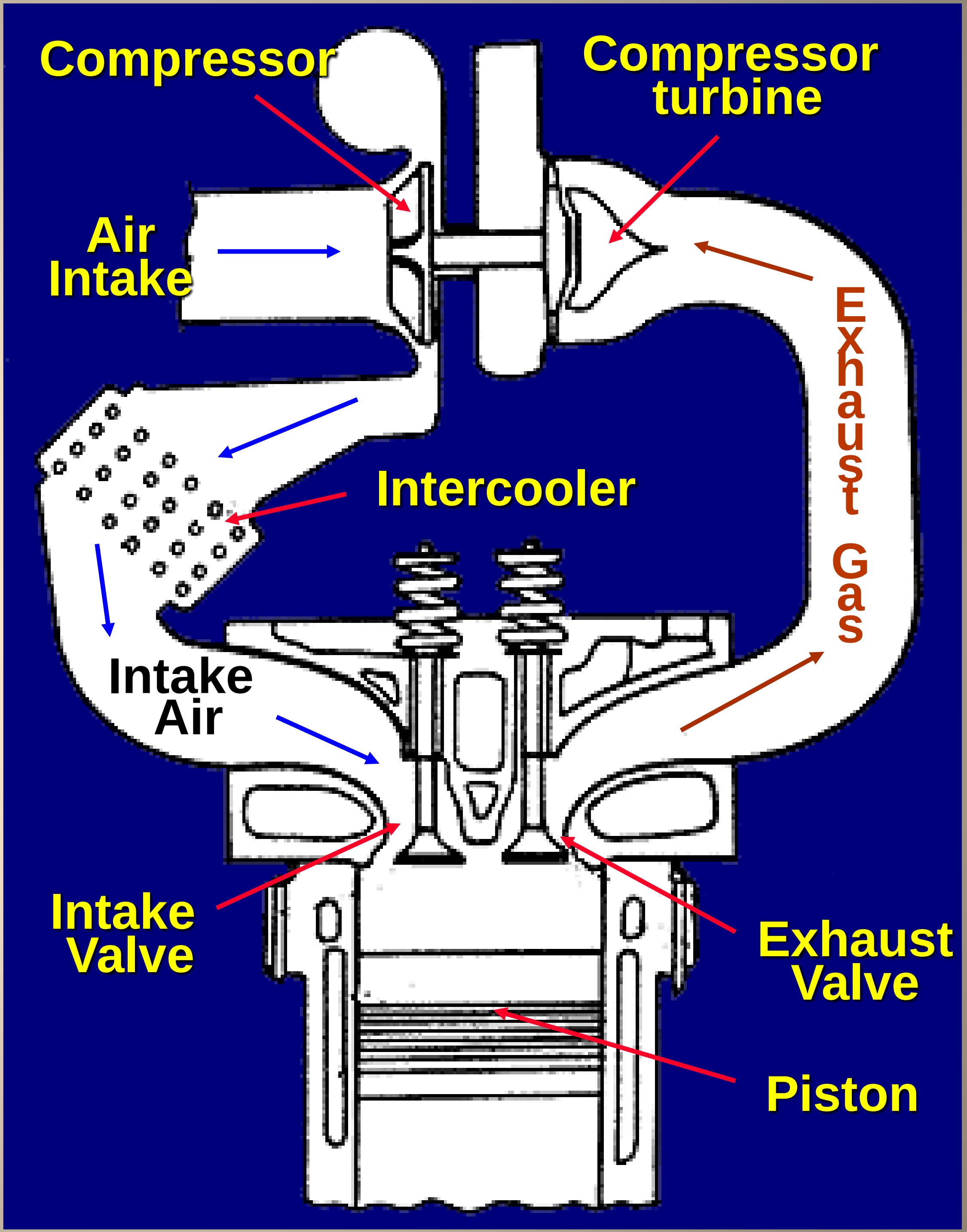
Turbochargers



Turbocharger

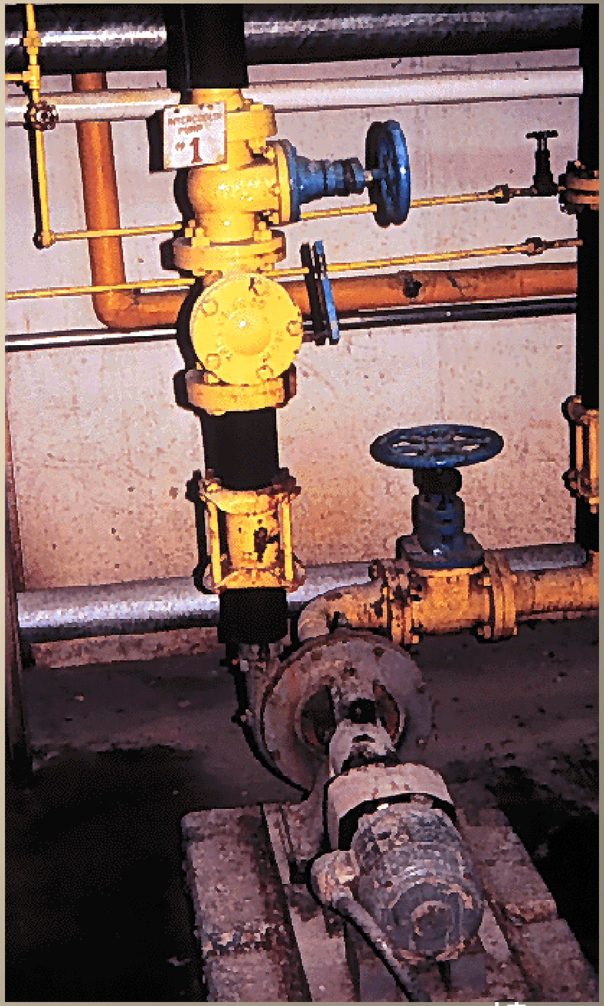


Turbocharger



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_2 , O_2)

→

H_2O

CO_2

CO

HC

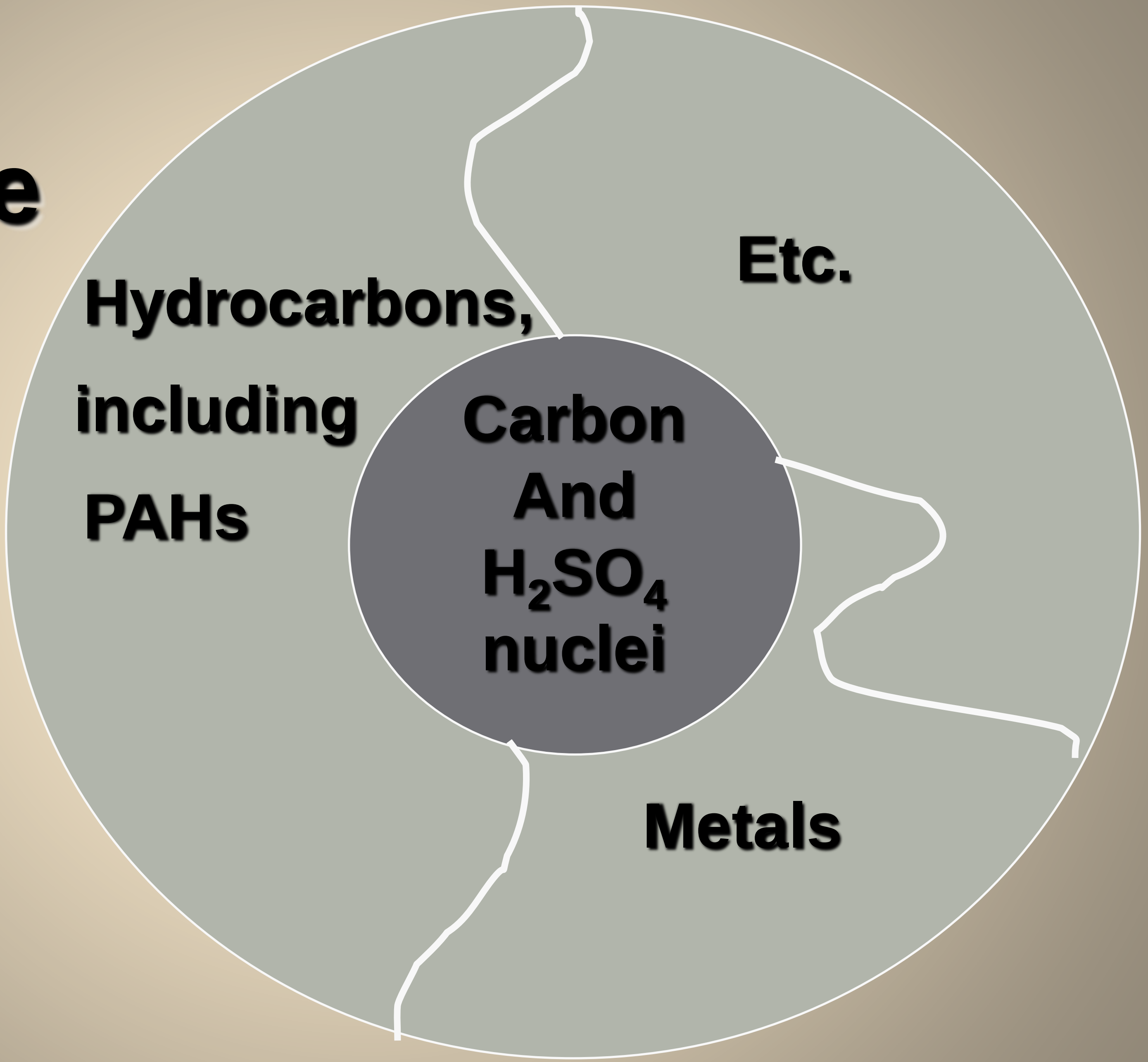
NO_x

SO_x

Aldehydes

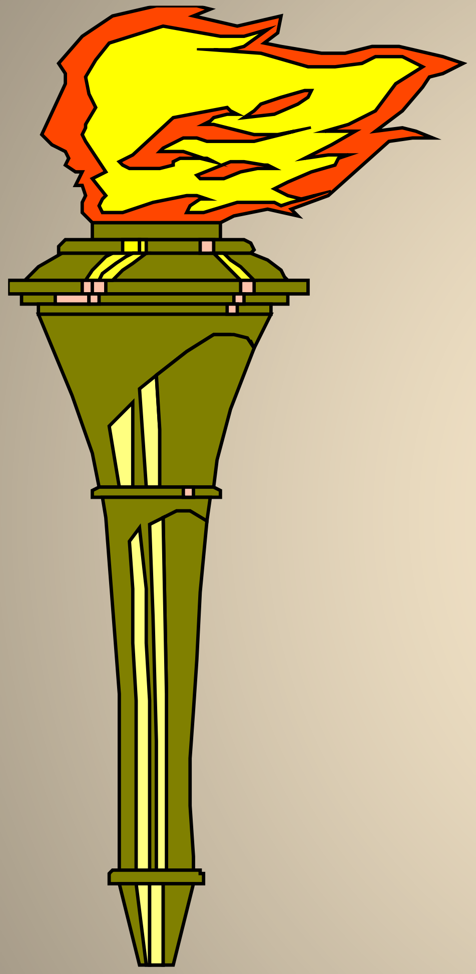
PM10

Diesel Particulate Matter



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



- Time
- Temperature
- Turbulence
- Oxygen

Stoichiometric Ration

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

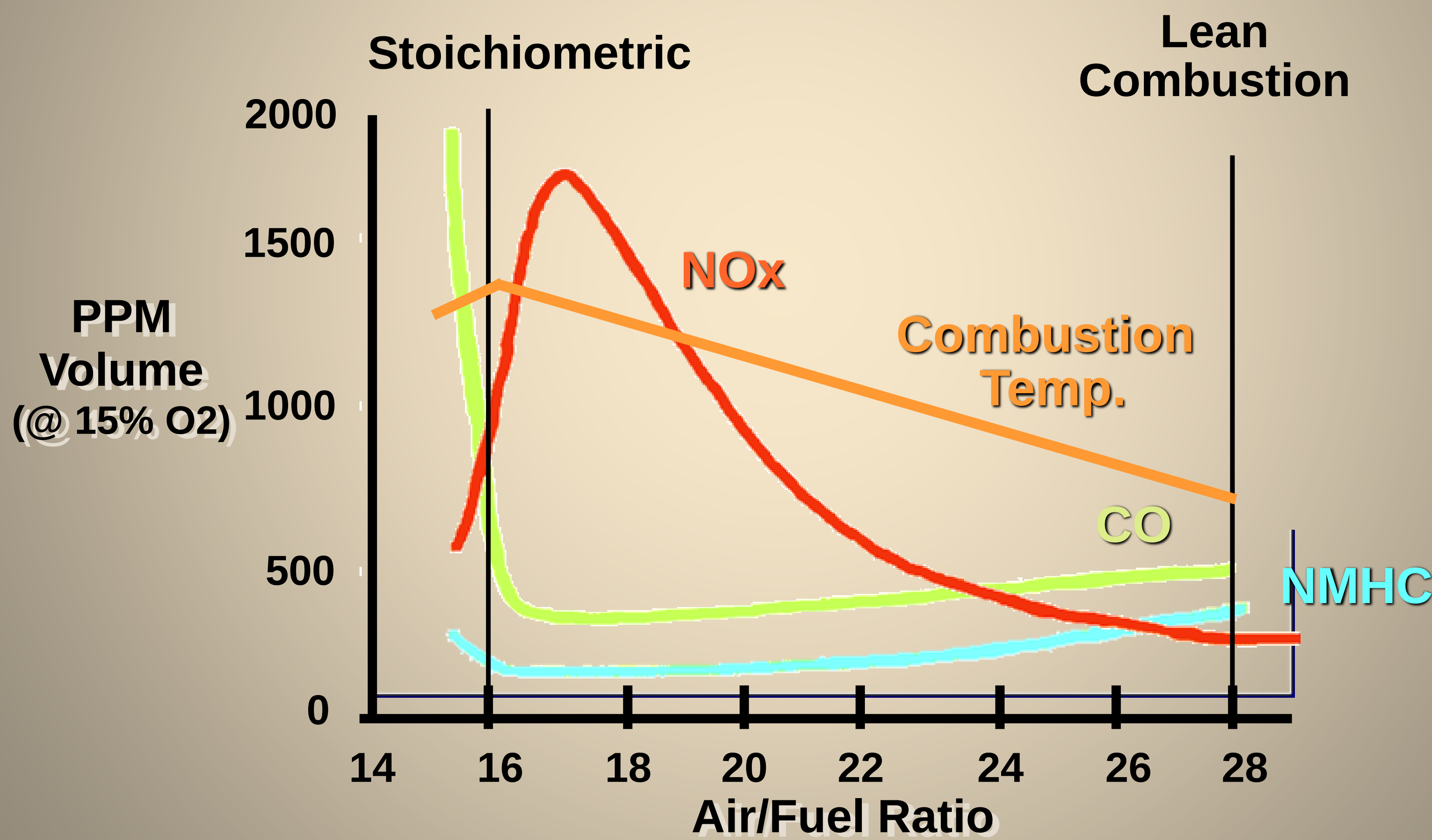
For Gasoline:

	AIR	FUEL
MASS	14.7	1
VOLUME	11,500	1

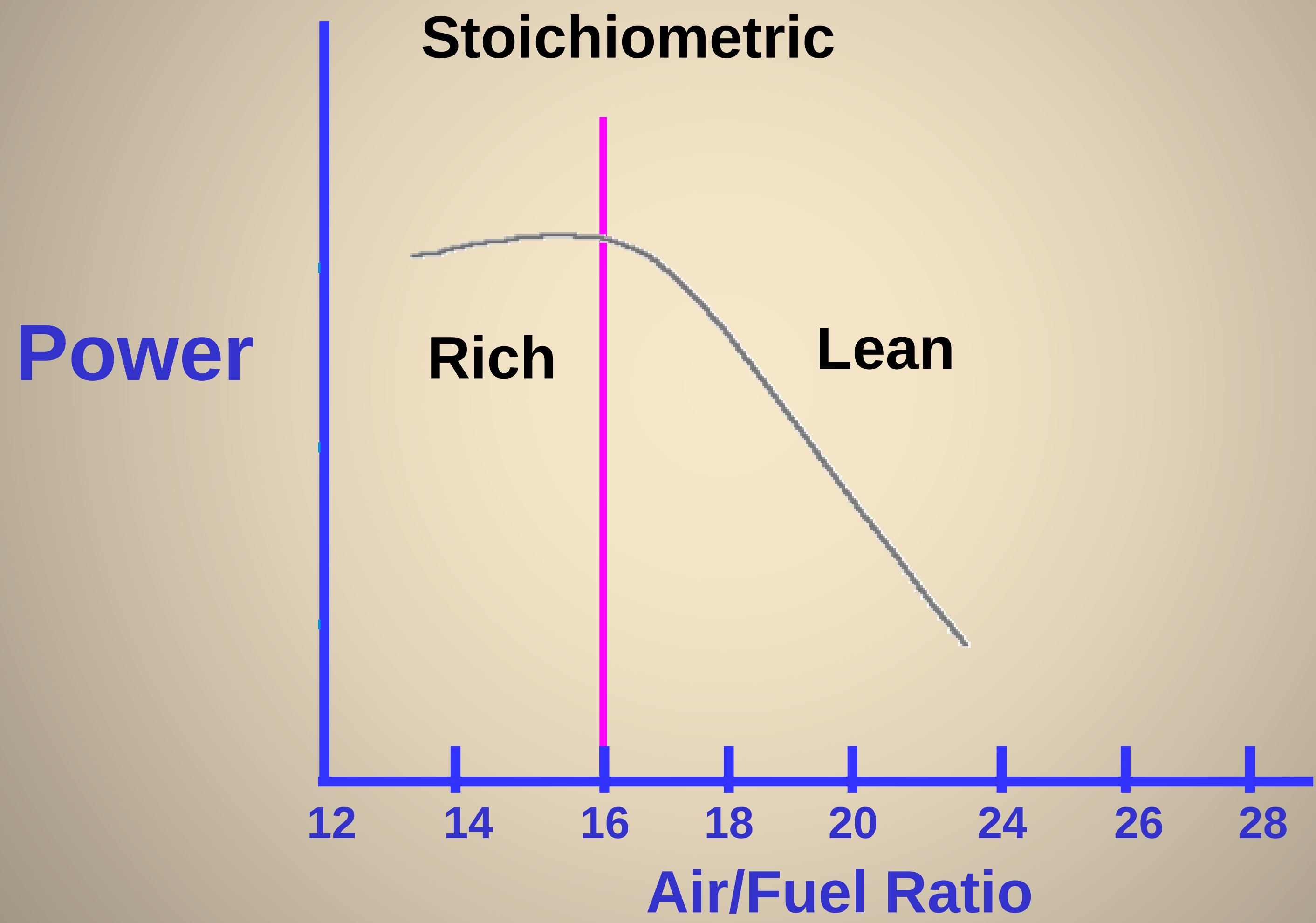
RICH = Less than 14.7:1

LEAN = Greater than 14.7:1

Exhaust Emissions and A/F (Natural Gas Engine)

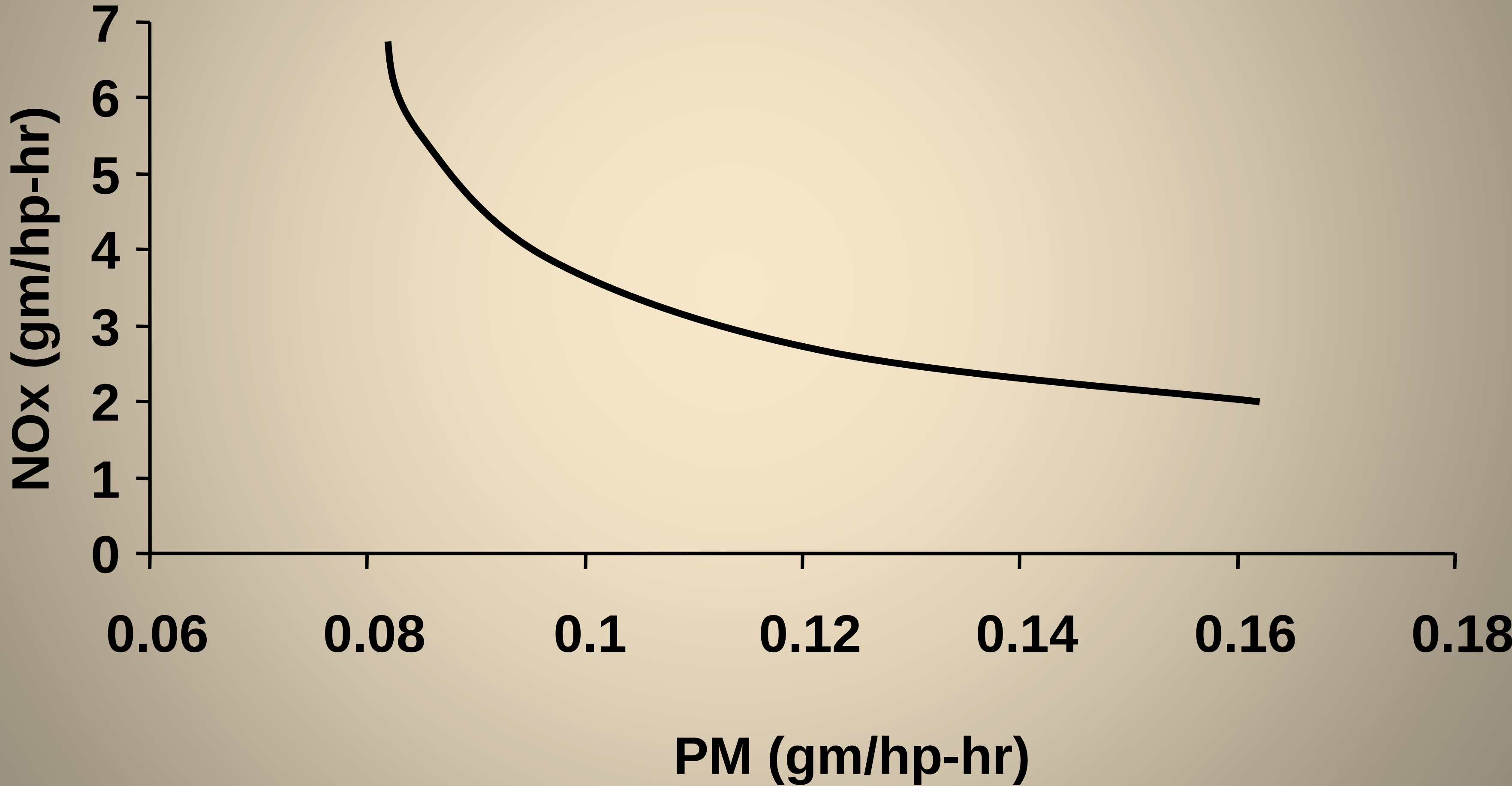


Engine Power and A/F



Generalized NOx vs. PM

(for ‘96 engines)



Mechanisms of Formation

Mechanisms of Formation for Some Common Chemicals	
CO	Incomplete Combustion
NOx	High temperature combustion of N2
HC	Unburnt or partially burnt fuel
SOx	Oxidation of sulfur
PM10	Partial combustion of engine oil. Partially burn fuel

Factors Affecting Emissions

- Engine Design
- Fuel Type
- Atmospheric Conditions
- Operating Conditions
- Tuning and Maintenance

Emission Control Methods for Compression 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

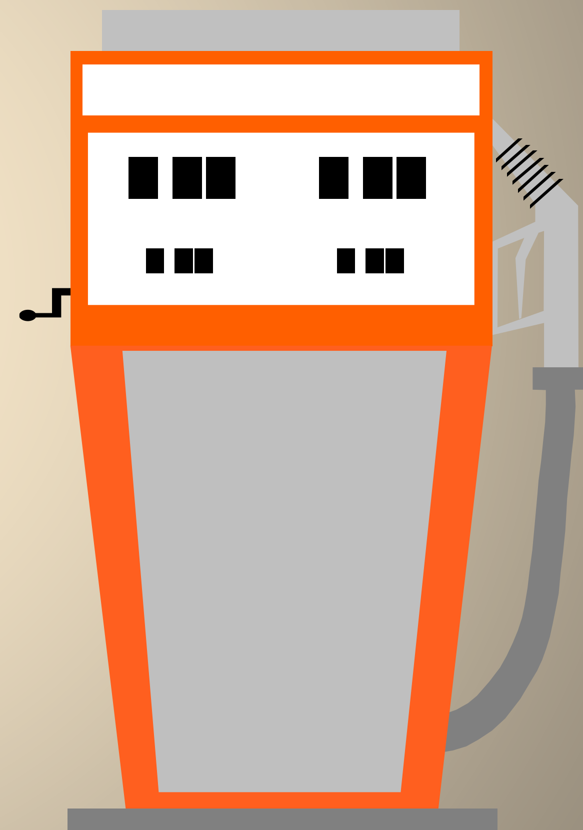
Emission Control Methods for Compression Ignited Engines

PM Control

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

Fuel Type

- Gaseous Fuels
- Diesel
- Liquid Fuels
- Alternate Fuels



Reciprocating Engine Typical Emission Levels

Engine Type	Lambda*(ë)	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

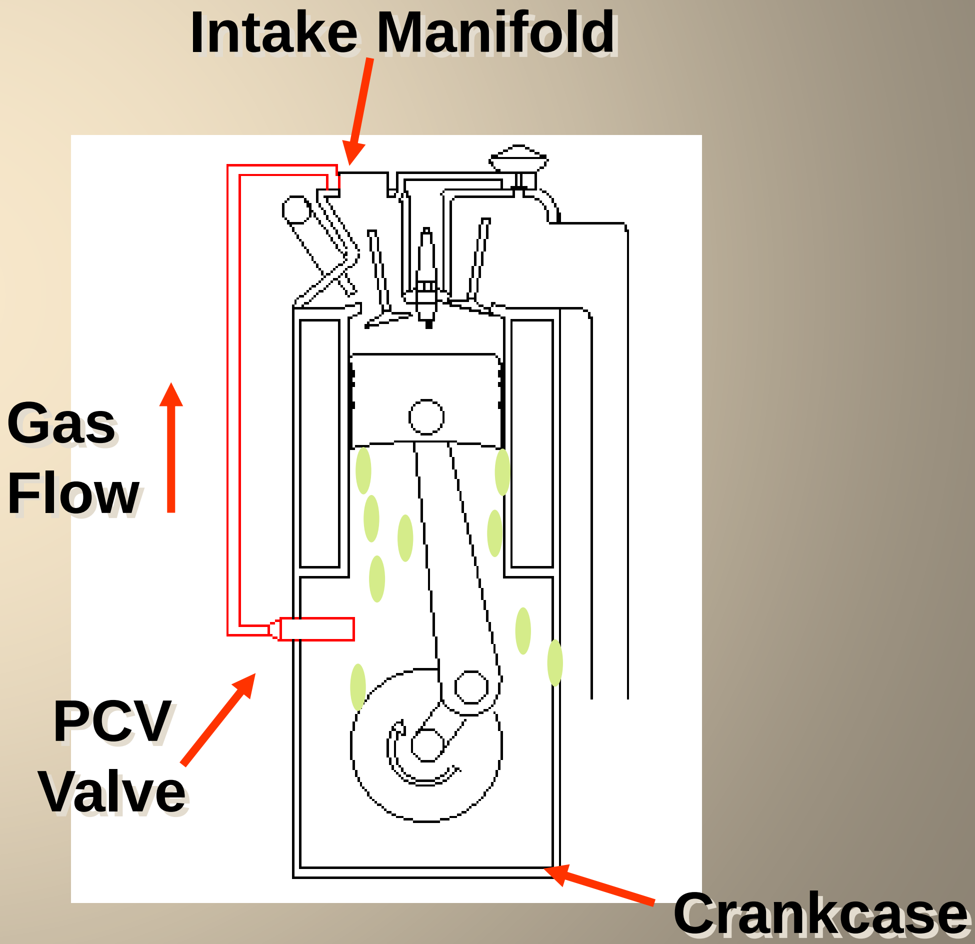
from: *Emission Control Technology for Stationary Internal Combustion Engines*, MECA, July 1997, p. 3

Percentage of Gaseous Compounds in Gaseous Fuels

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

Positive Crankcase Ventilation (PCV) Systems

- 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



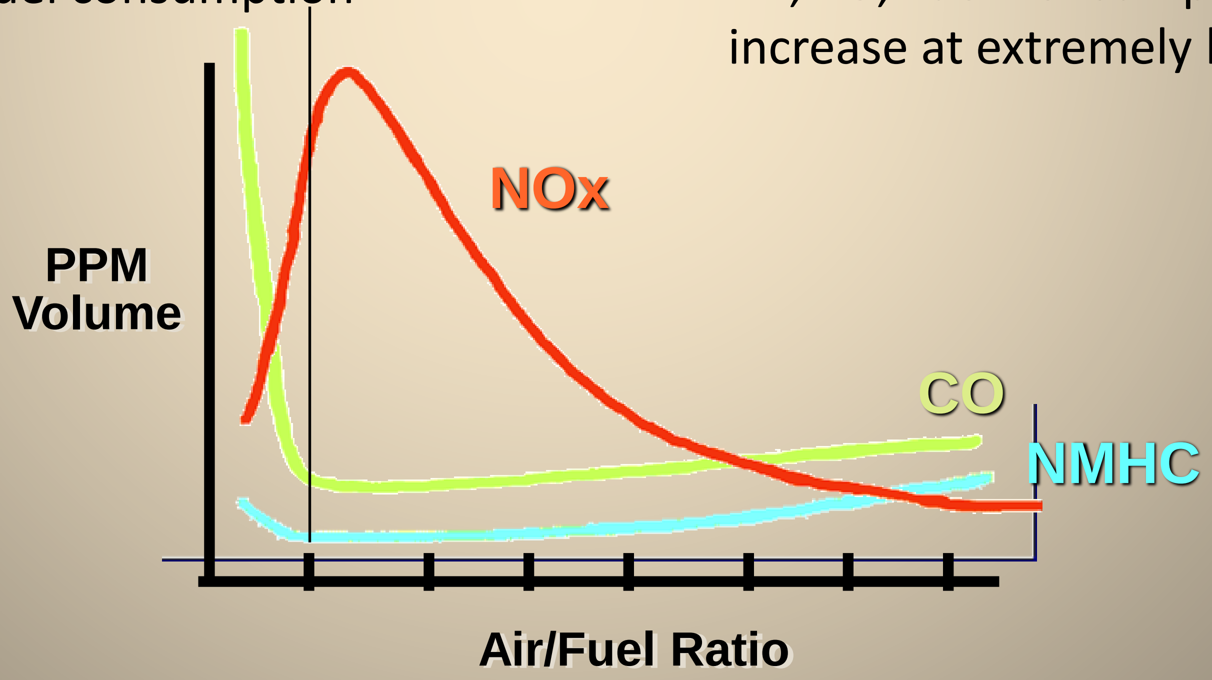
Air-Fuel Ratio Adjustment

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



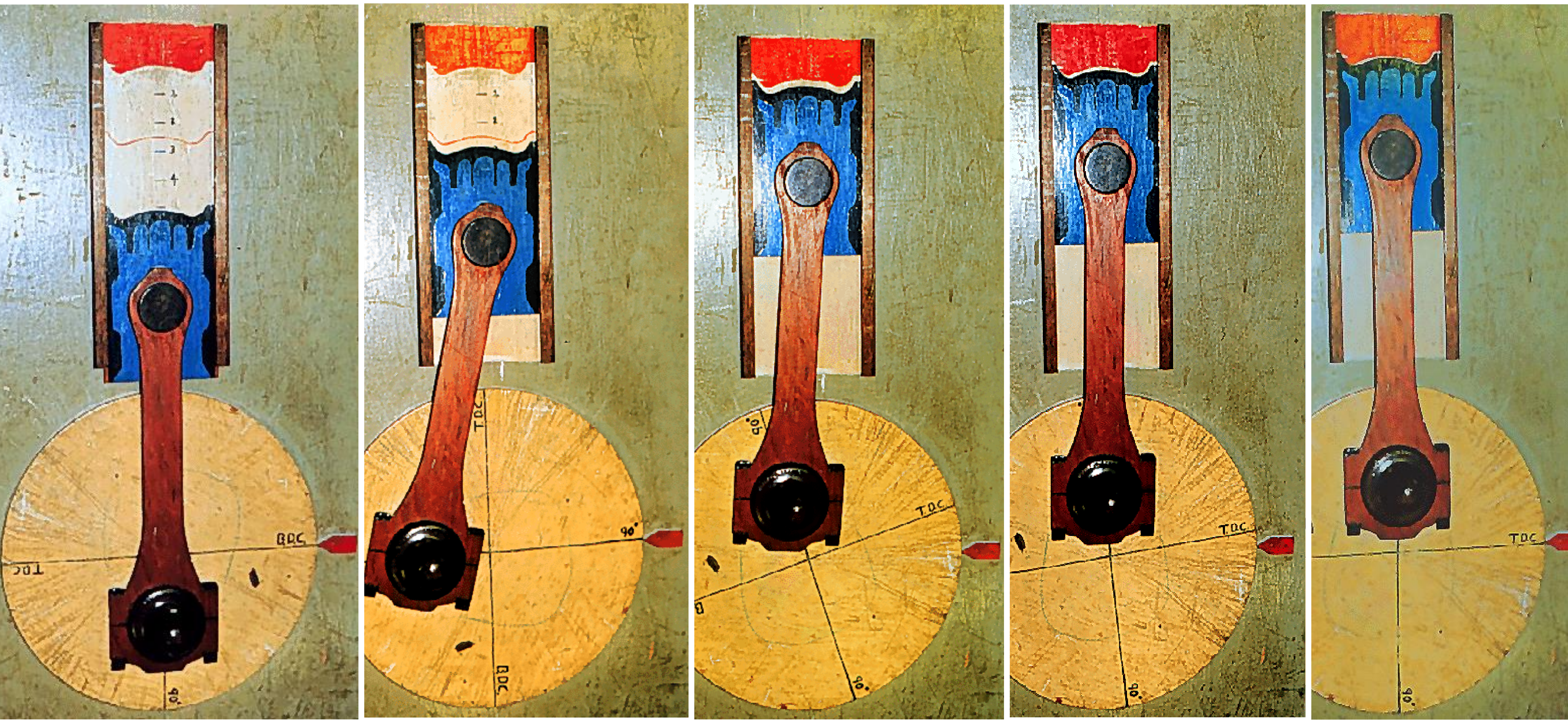
Piston at Bottom Dead Center

Piston at 90° Before Top Dead Center

Piston at ~15° Before Top Dead Center

Piston at ~5° Before Top Dead Center
Timing Retarded 10°

Piston at Top Dead Center



NOx Reductions vs. Ignition Retard for Lean Burn Engines

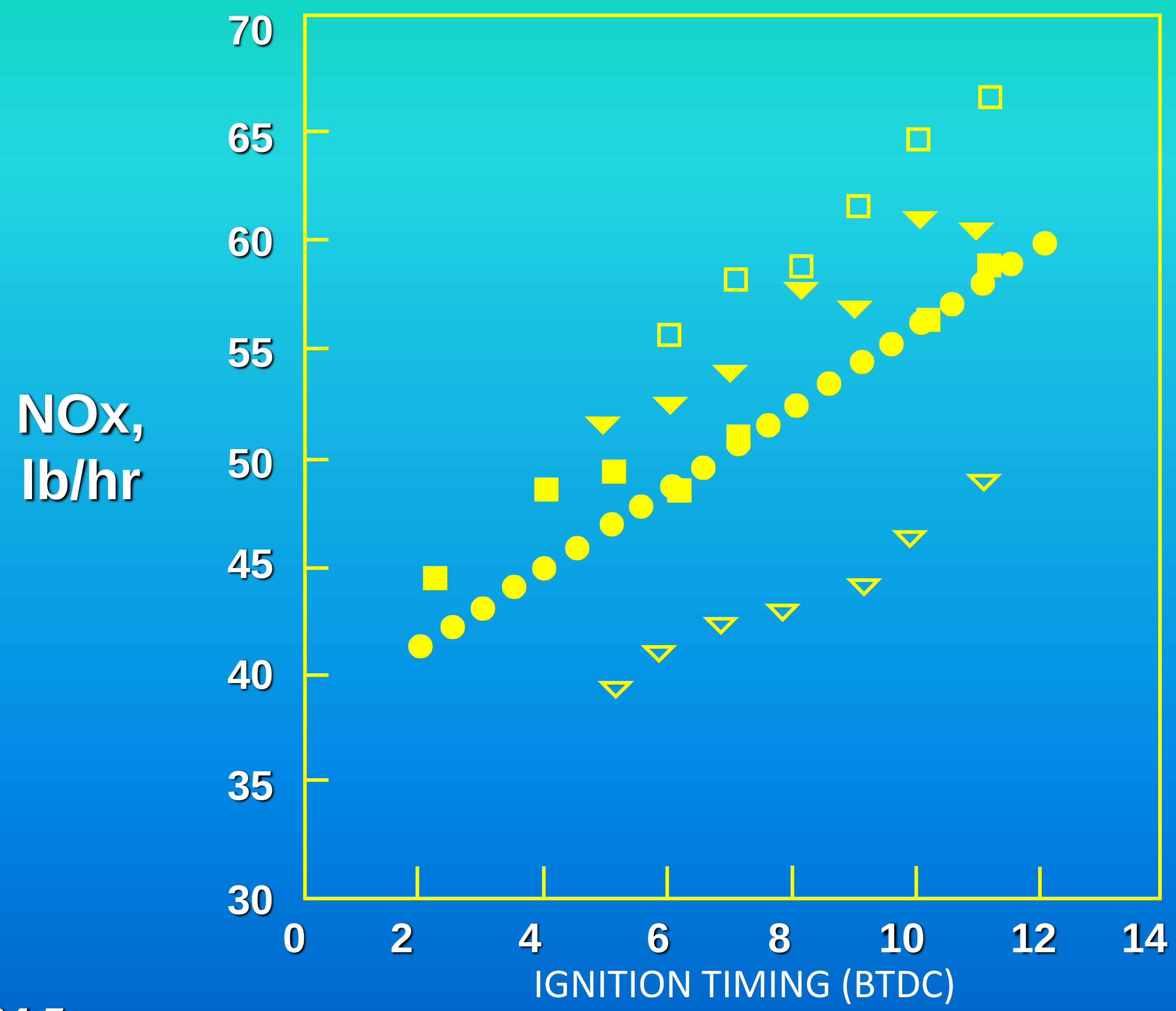


Figure 304.5

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

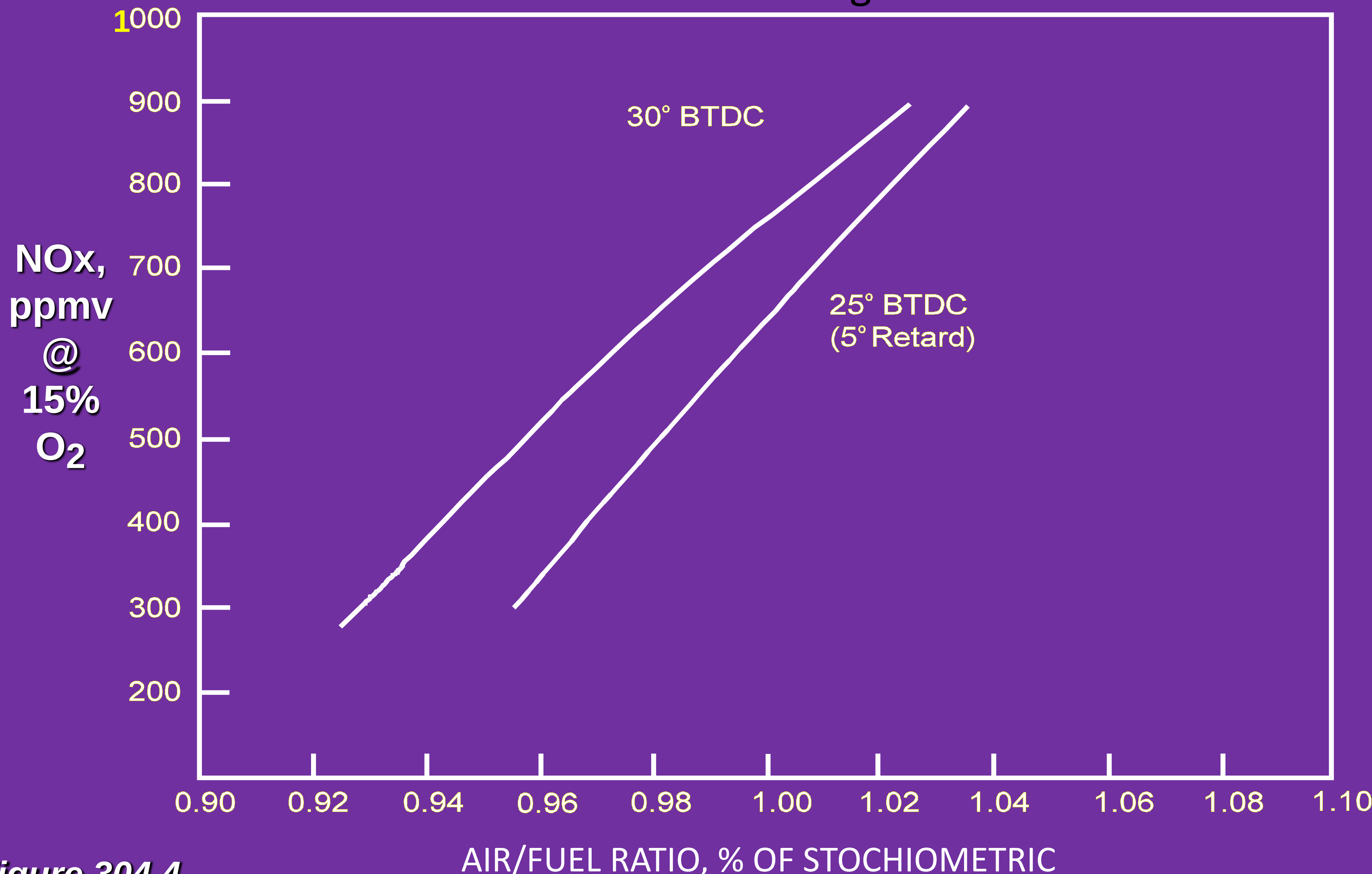


Figure 304.4

Timing Retard

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

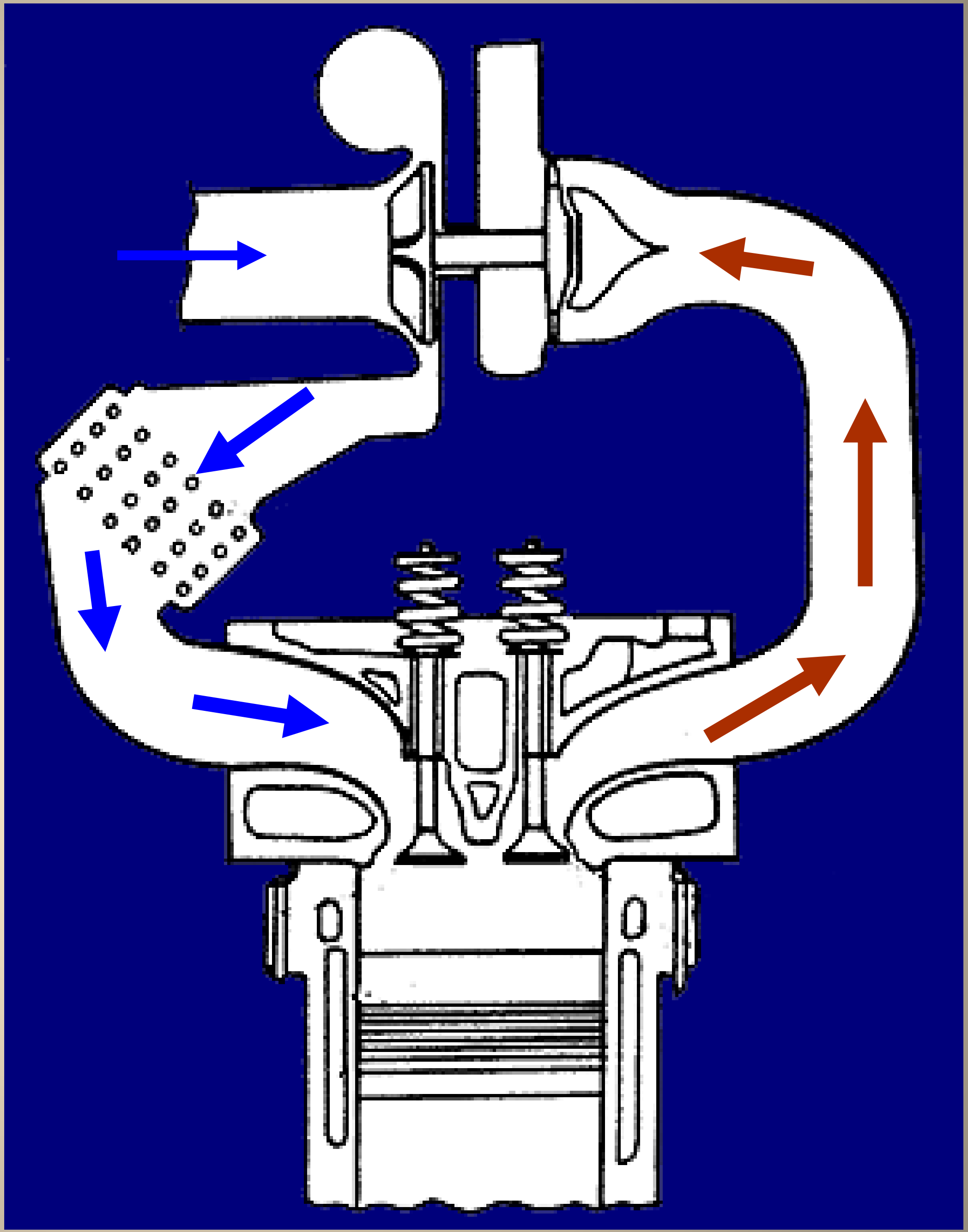
Advantages

low capital, operating costs
easy to adjust
minimal increase in CO, HC

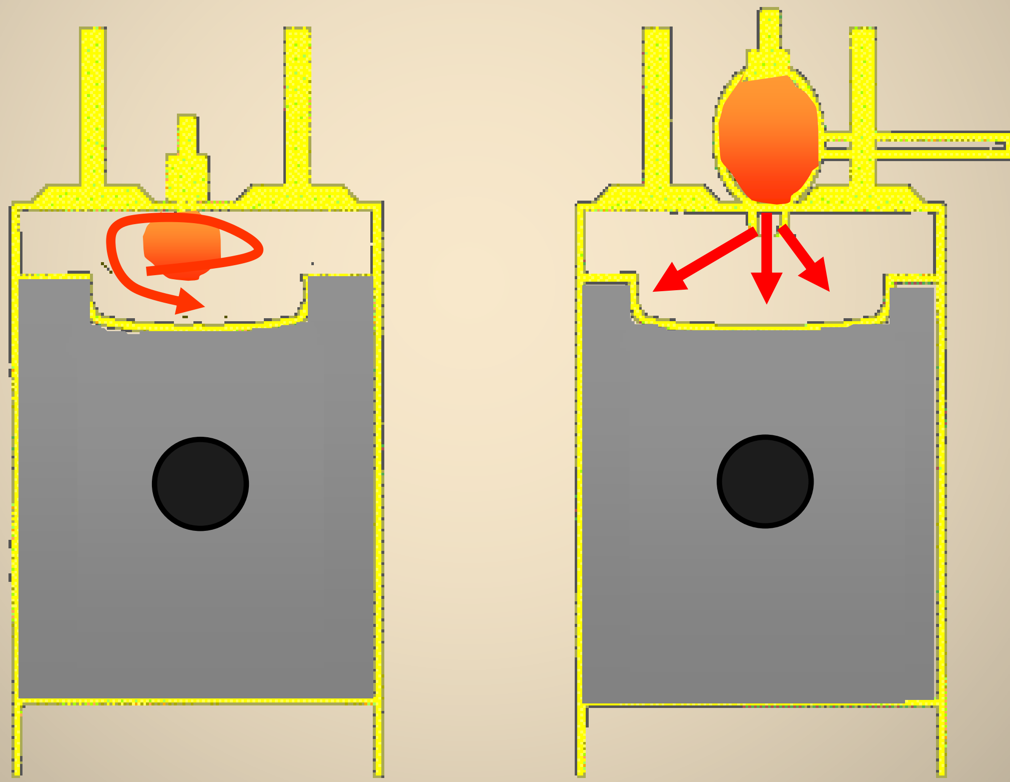
Disadvantages

reduce max power output
reduce fuel efficiency
may increase PM (smoke) in C-I
may increase exhaust temps

Turbocharger with Intercooler



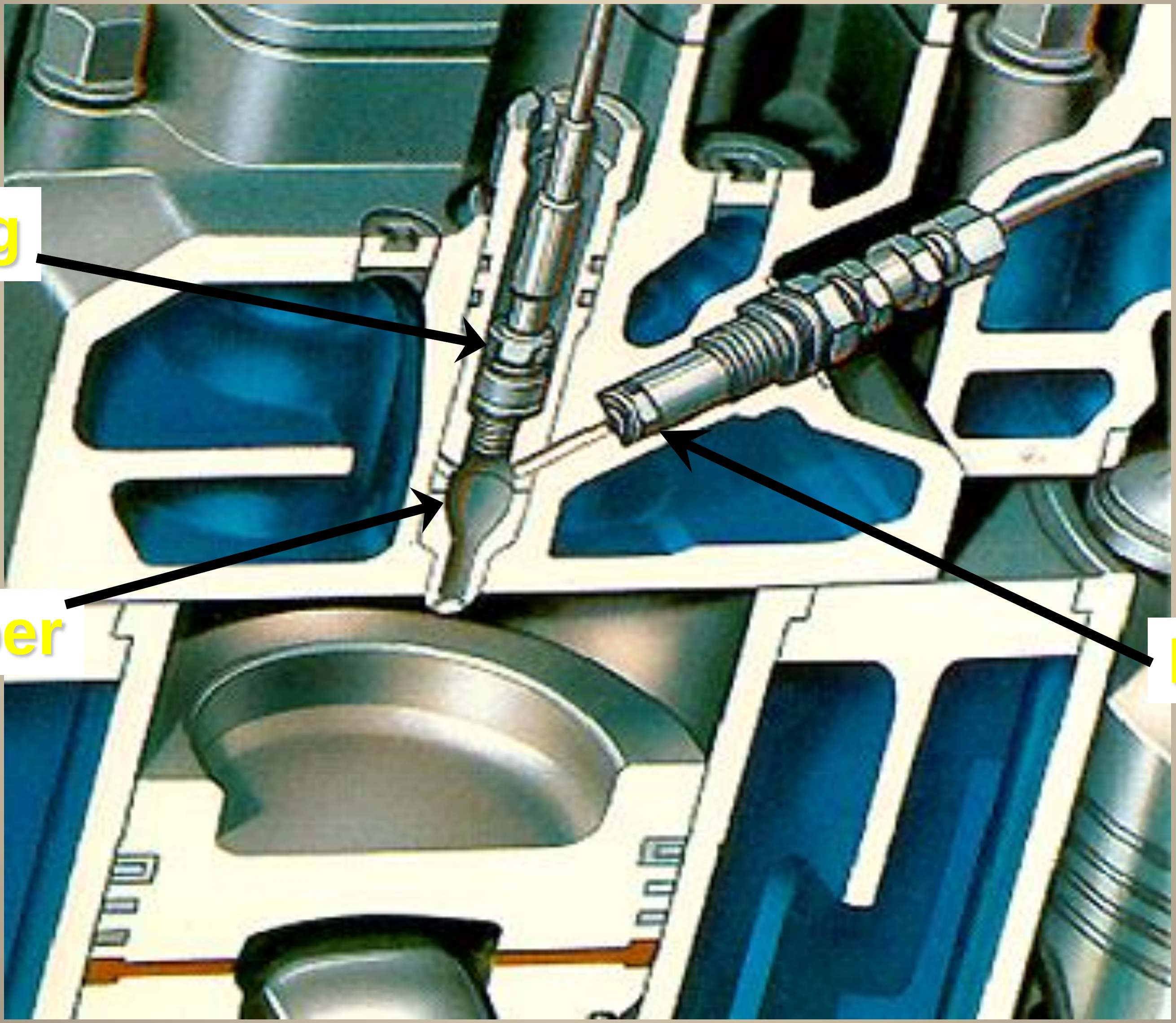
Low-Emission Combustion or "CleanBurn®" Engine



Open Chamber Prechamber

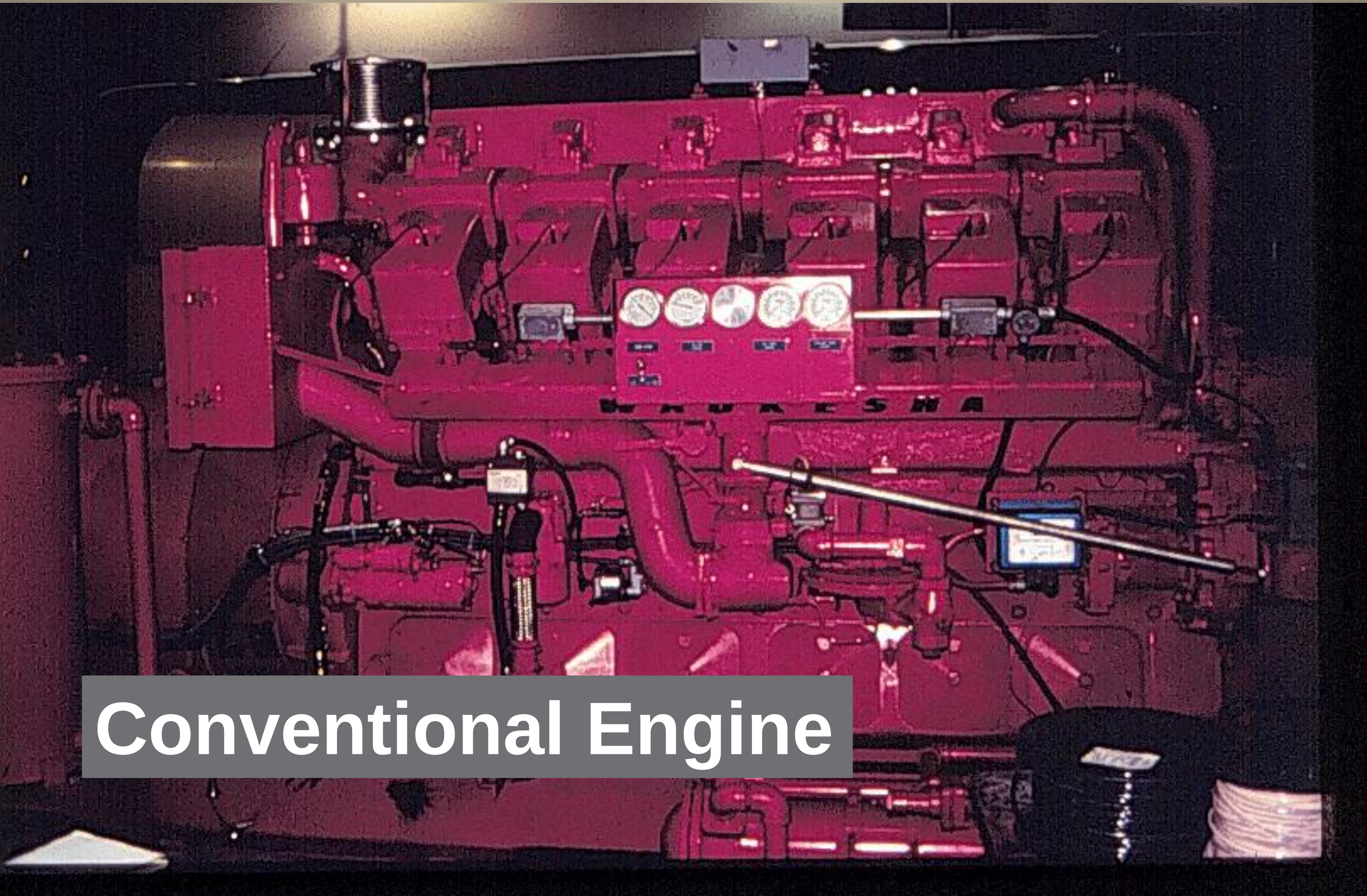
Courtesy Waukesha

Pre-Chamber System



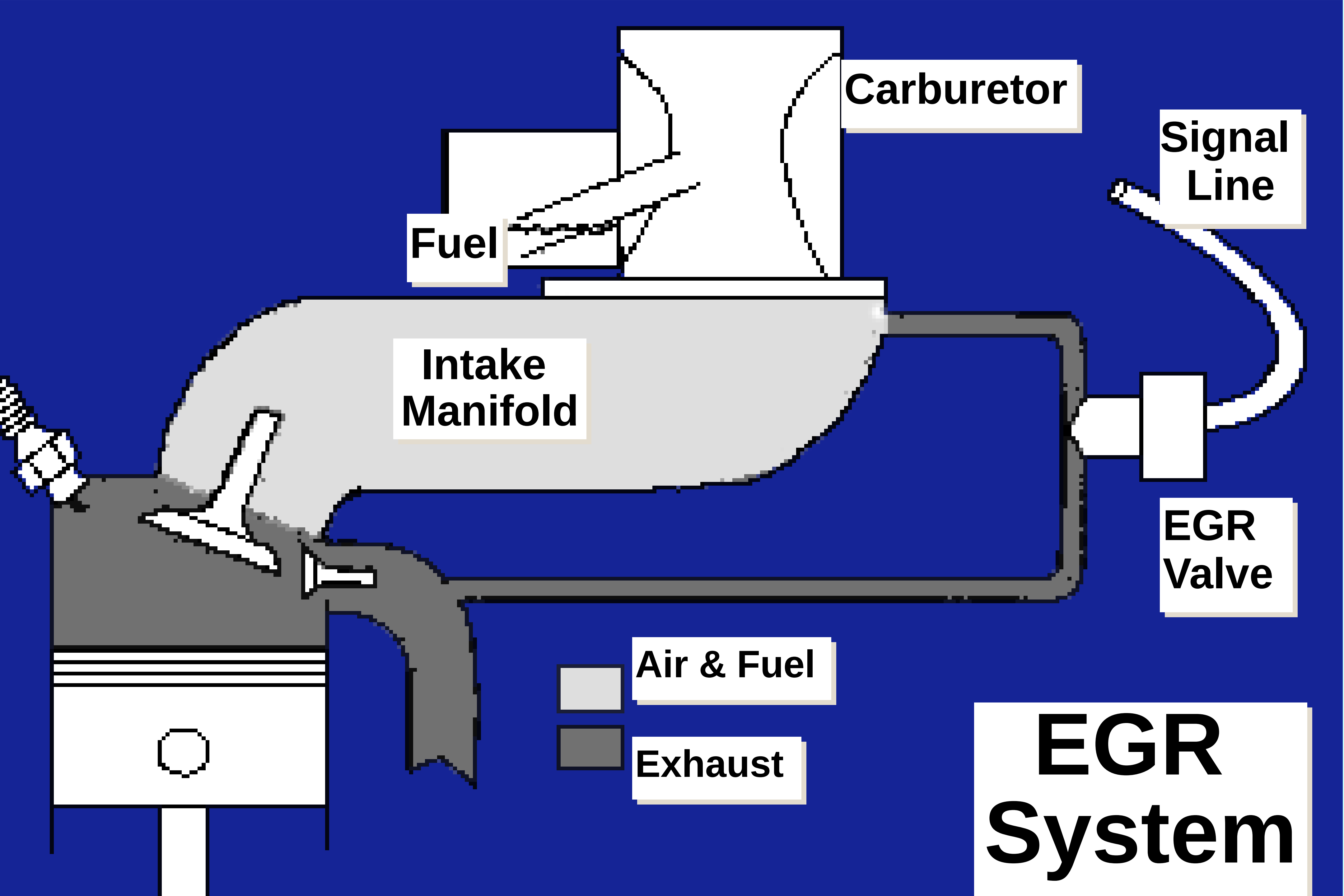
Courtesy Waukesha

Lean-Burn Retrofit Kit

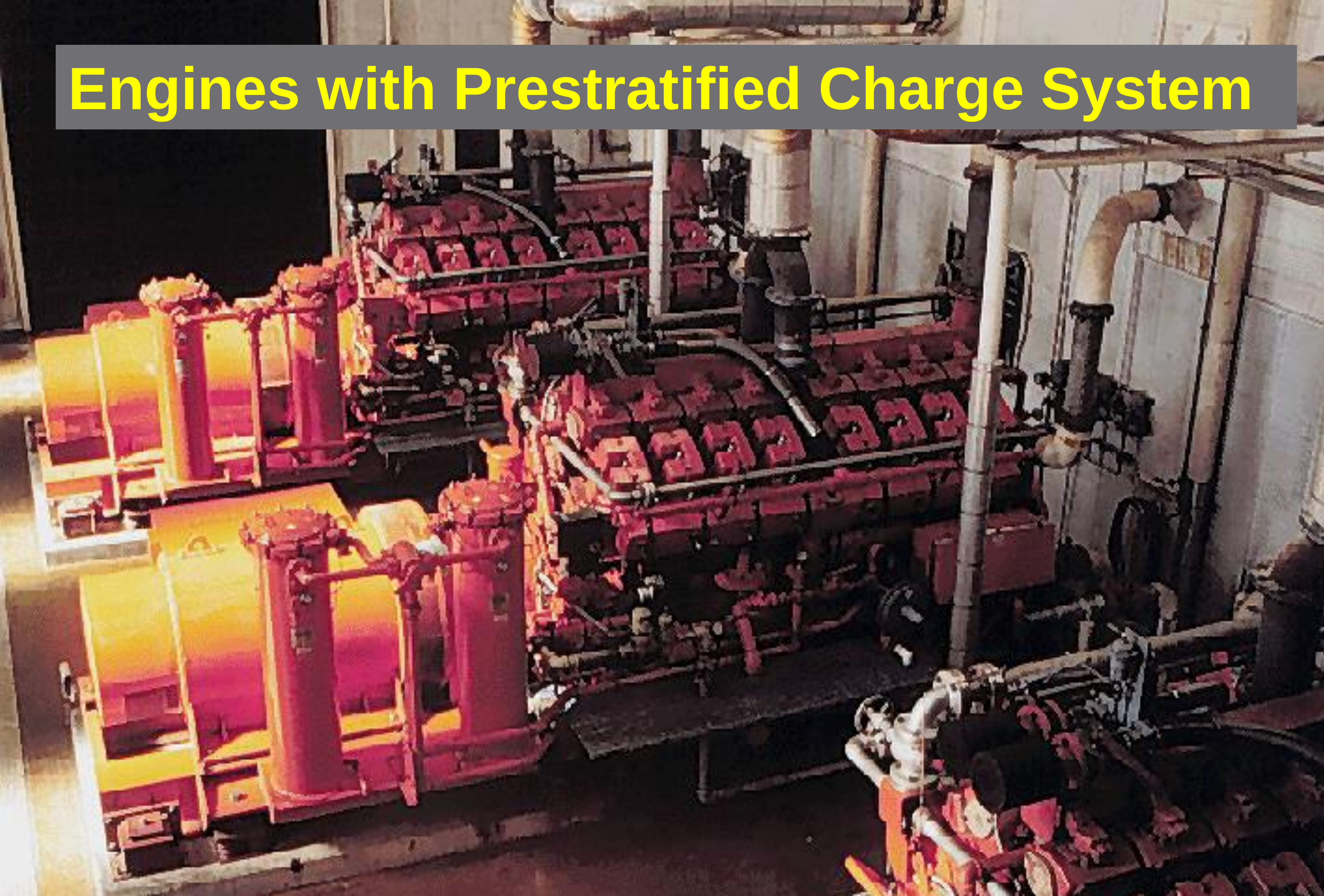


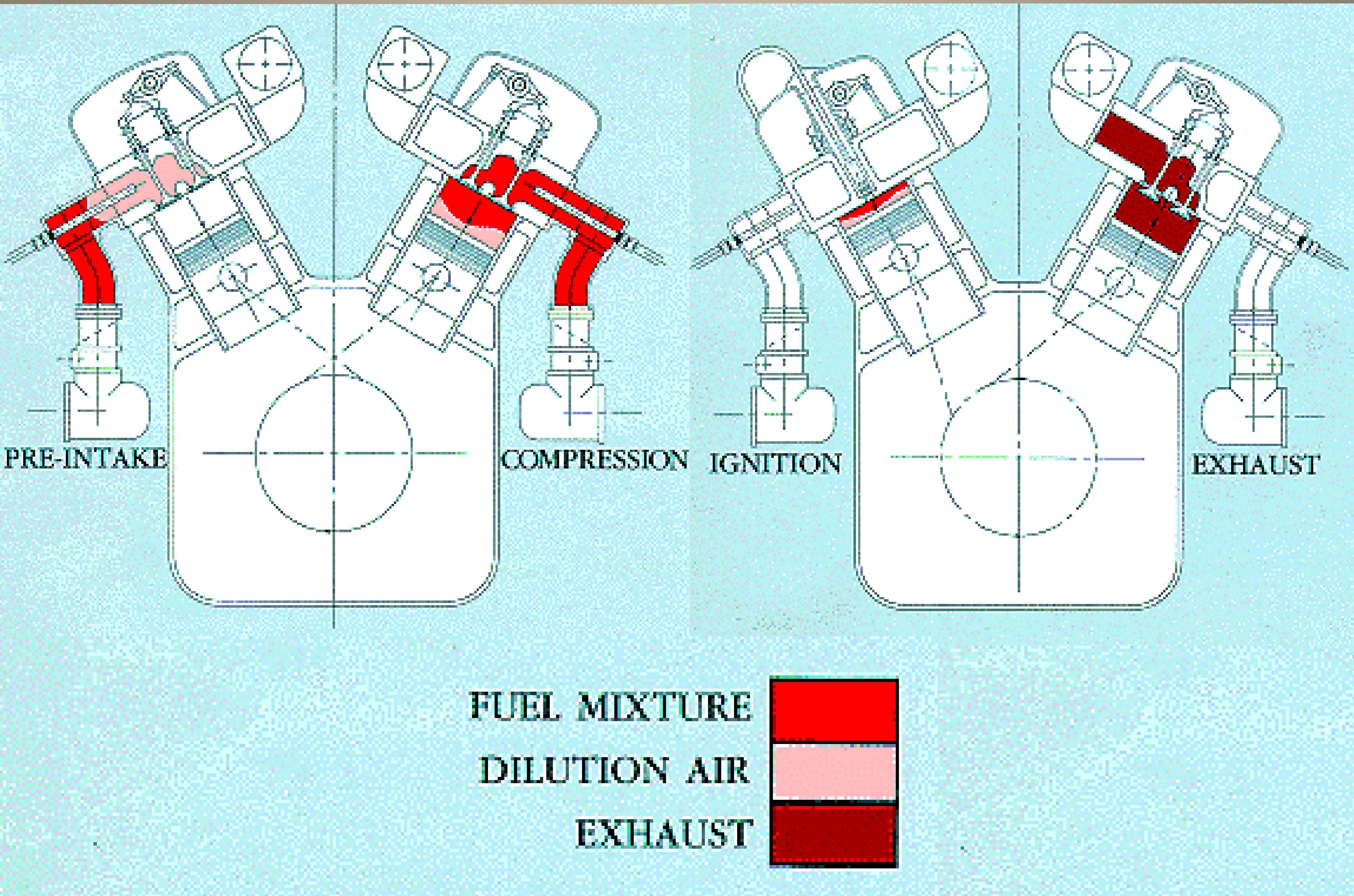
Conventional Engine


Lean-Burn Retrofit


Carburetor
Signal Line
Fuel
Intake Manifold
EGR Valve
Air & Fuel
Exhaust
EGR System

Engines with Prestratified Charge System

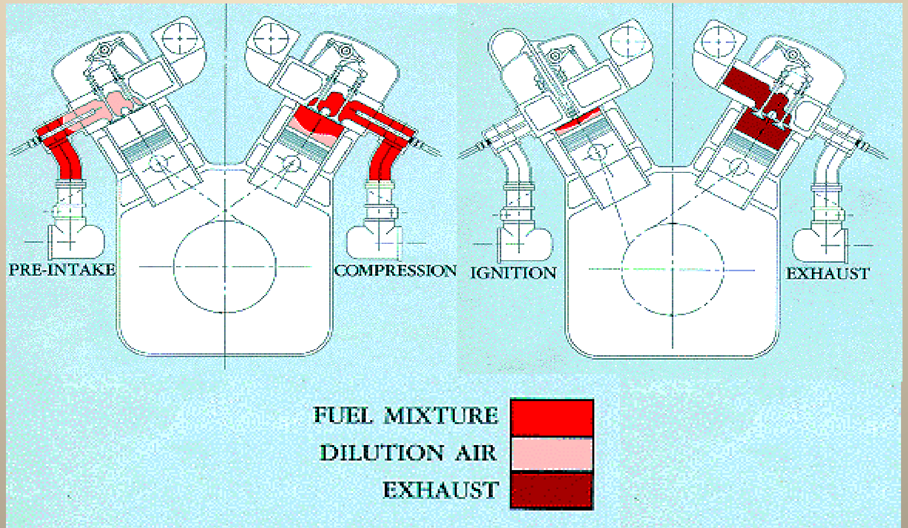



PRE-INTAKE
COMPRESSION
IGNITION
EXHAUST
FUEL MIXTURE
DILUTION AIR
EXHAUST


PSC® Retrofit
CATERPILLAR

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

CO is oxidized ---> CO_2

HC is oxidized ---> H_2O

} **OXIDATION CATALYST (Pt, Pd)**

NO_x is reduced ---> N_2 } **REDUCTION CATALYST (Rh)**

$CO + HC + NO_x \rightarrow CO_2 + H_2O + N_2$ } **THREE-WAY or NON-SELECTIVE CATALYST**

Dual-Bed Catalyst System

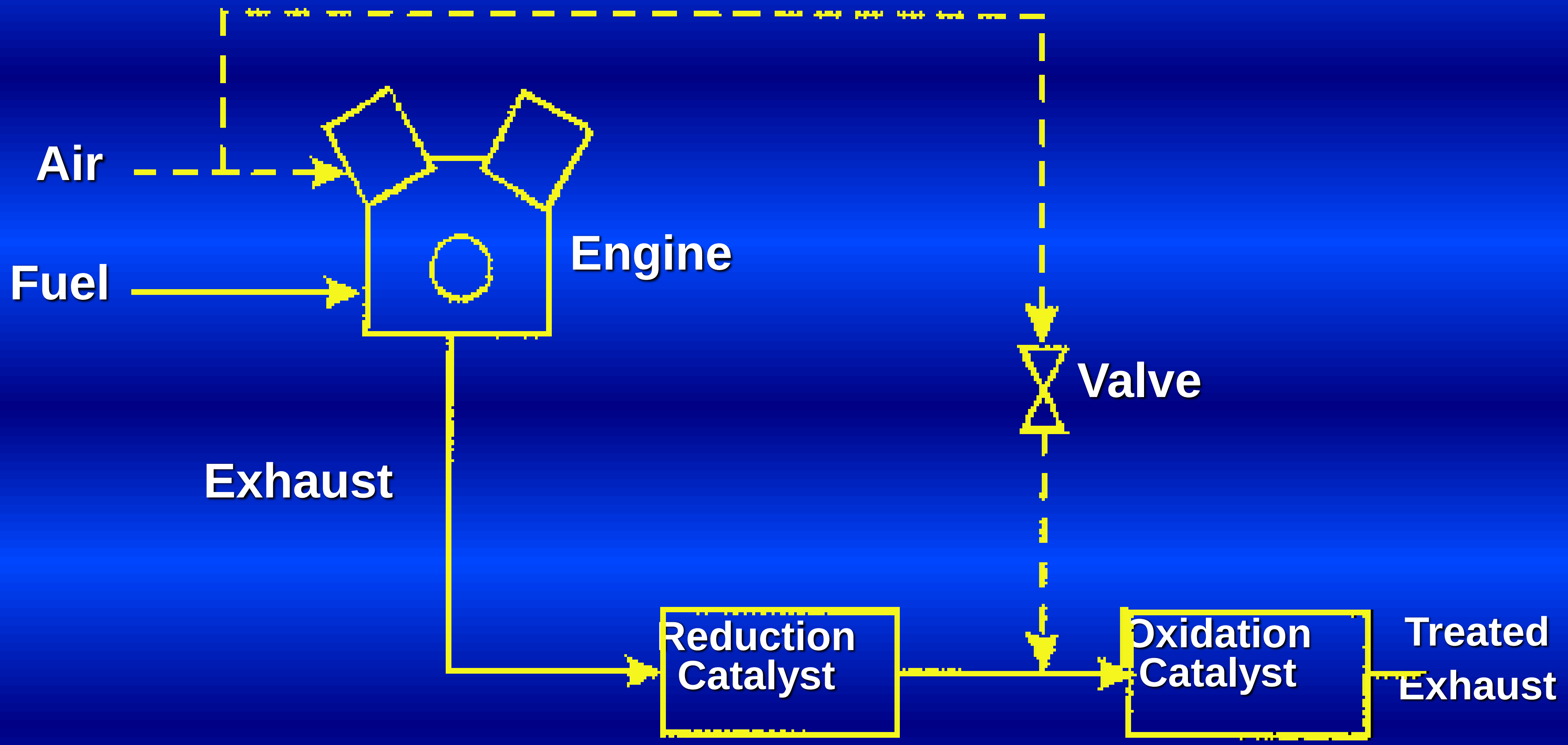
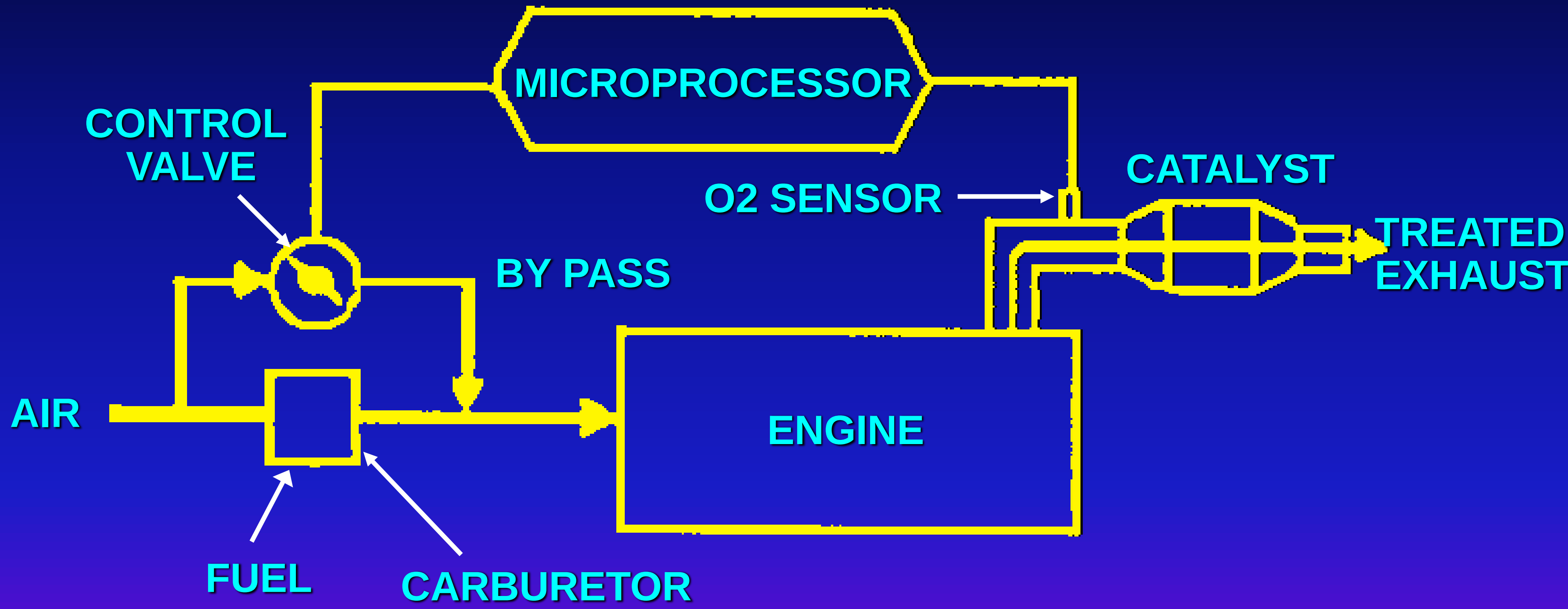


Figure 304.9

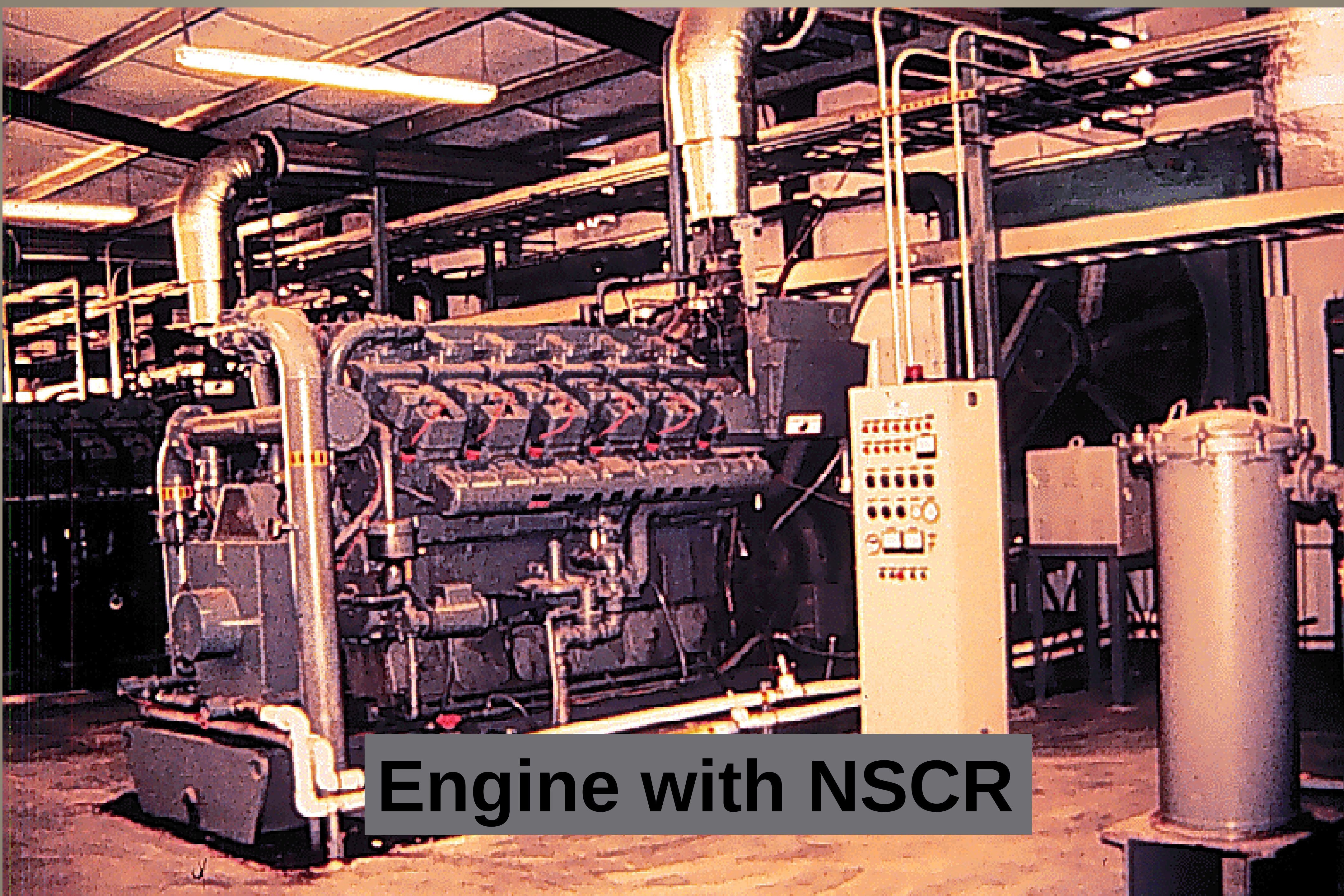
NSCR Catalyst System



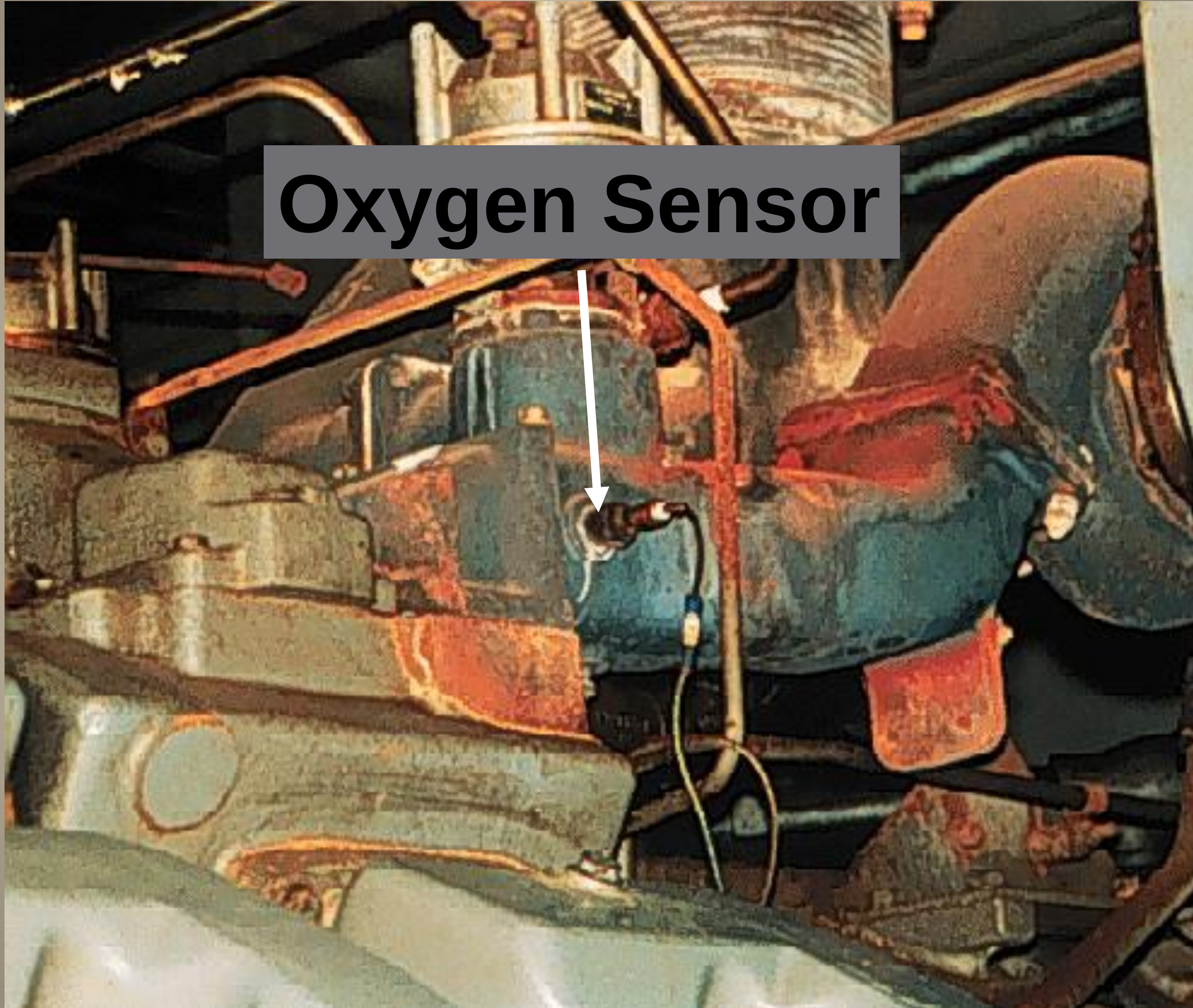
Courtesy Waukesha

Non-Selective Catalytic Reduction (NSCR)

- Converts NOx, CO, HCs → N_2, CO_2, H_2O
- Rich-burn engines only
- Natural gas applications mainly
- A/F must be precisely controlled → O_2 sensor
- Catalyst temperature 800º - 1200º F



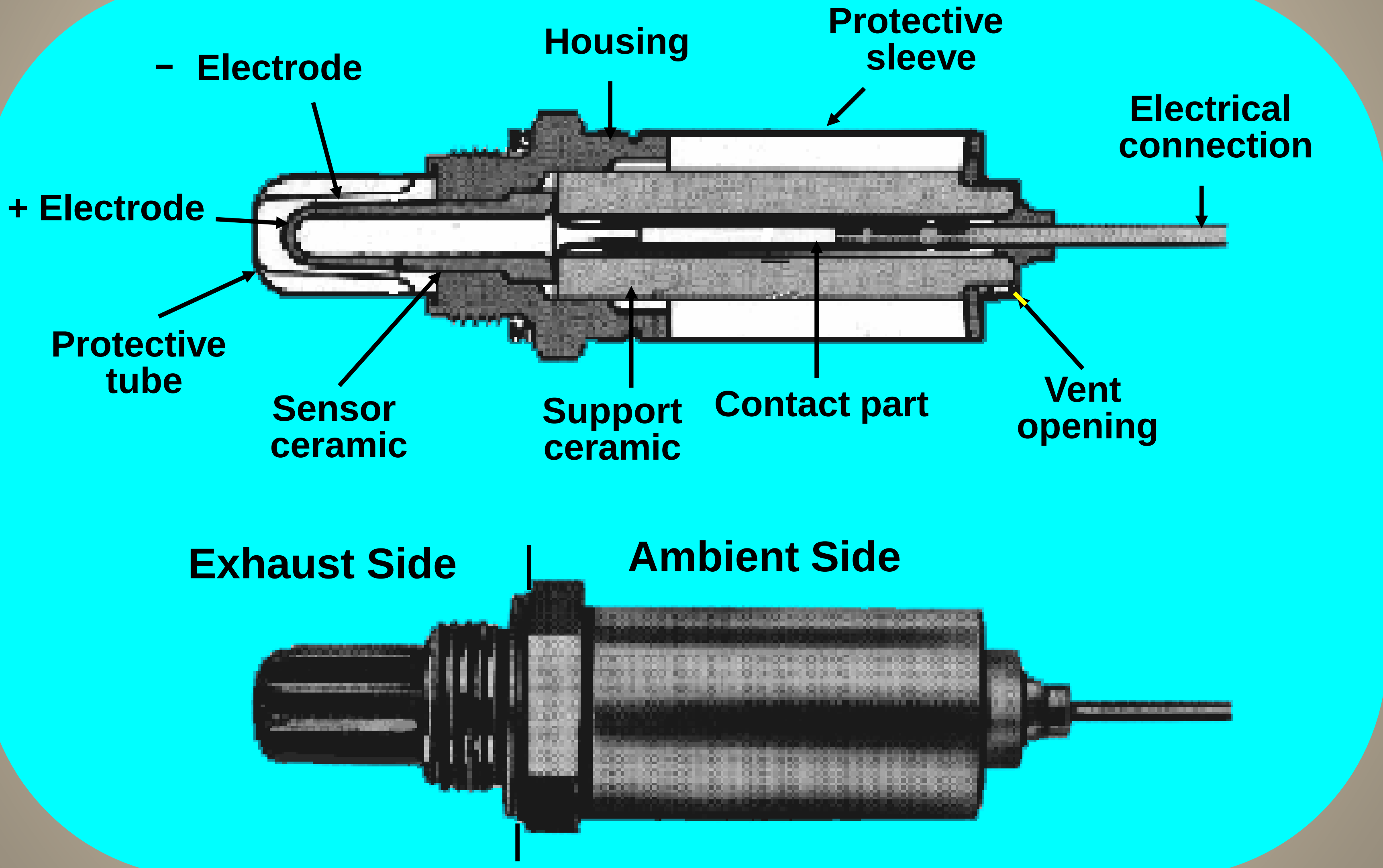
Engine with NSCR


Oxygen Sensor

Non-Selective Catalyst

Temperature Gauge

Oxygen Sensor



Source: Bosch

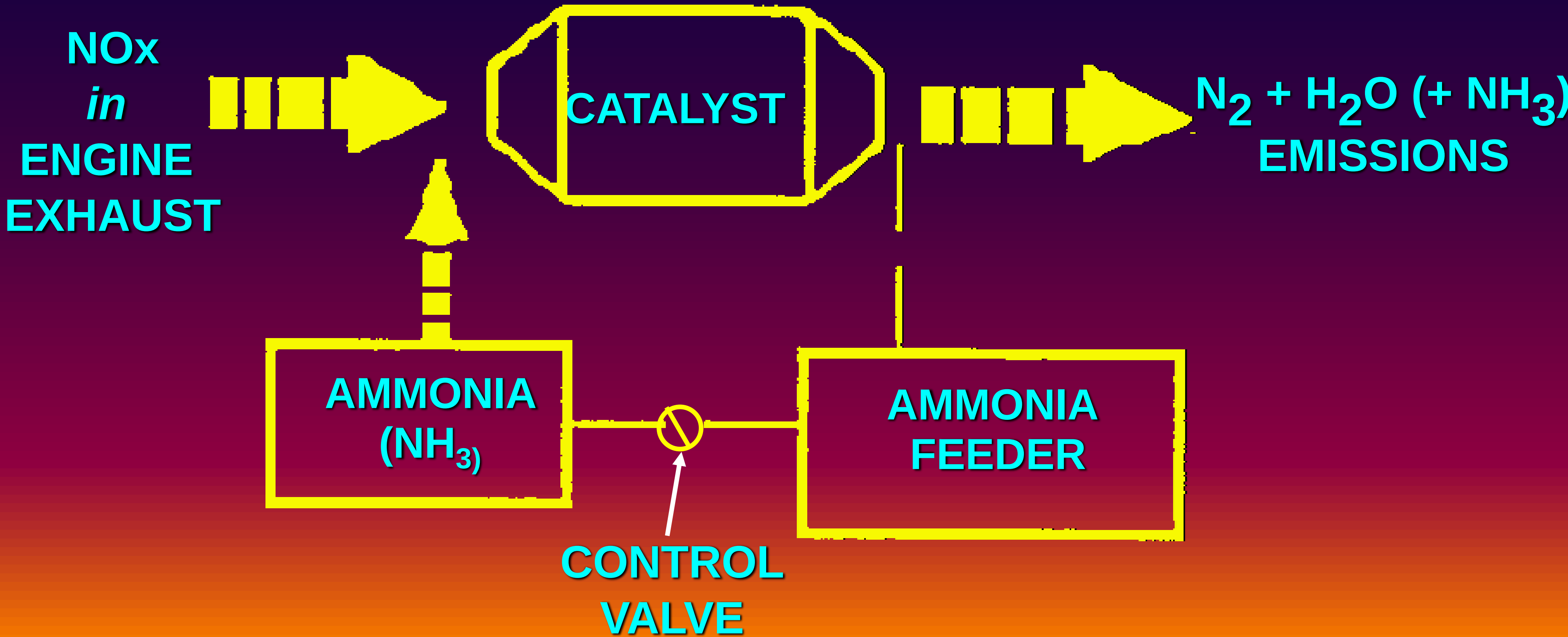
Lean NOx Catalyst

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

NOx Adsorbers ("Traps")

- NO catalytically oxidized to NO_2
- NO_2 stored in alkaline earth oxide as nitrate
- Stored NOx removed in two-step reduction process:
  - Temporary fuel-rich exhaust to release
  - NOx converted to N_2 over precious metal catalyst
- Engine management system needed
- 50 - 90% efficiency
- Sulfur poisoning

SCR System



Courtesy Waukesha

Major Parts of SCR System

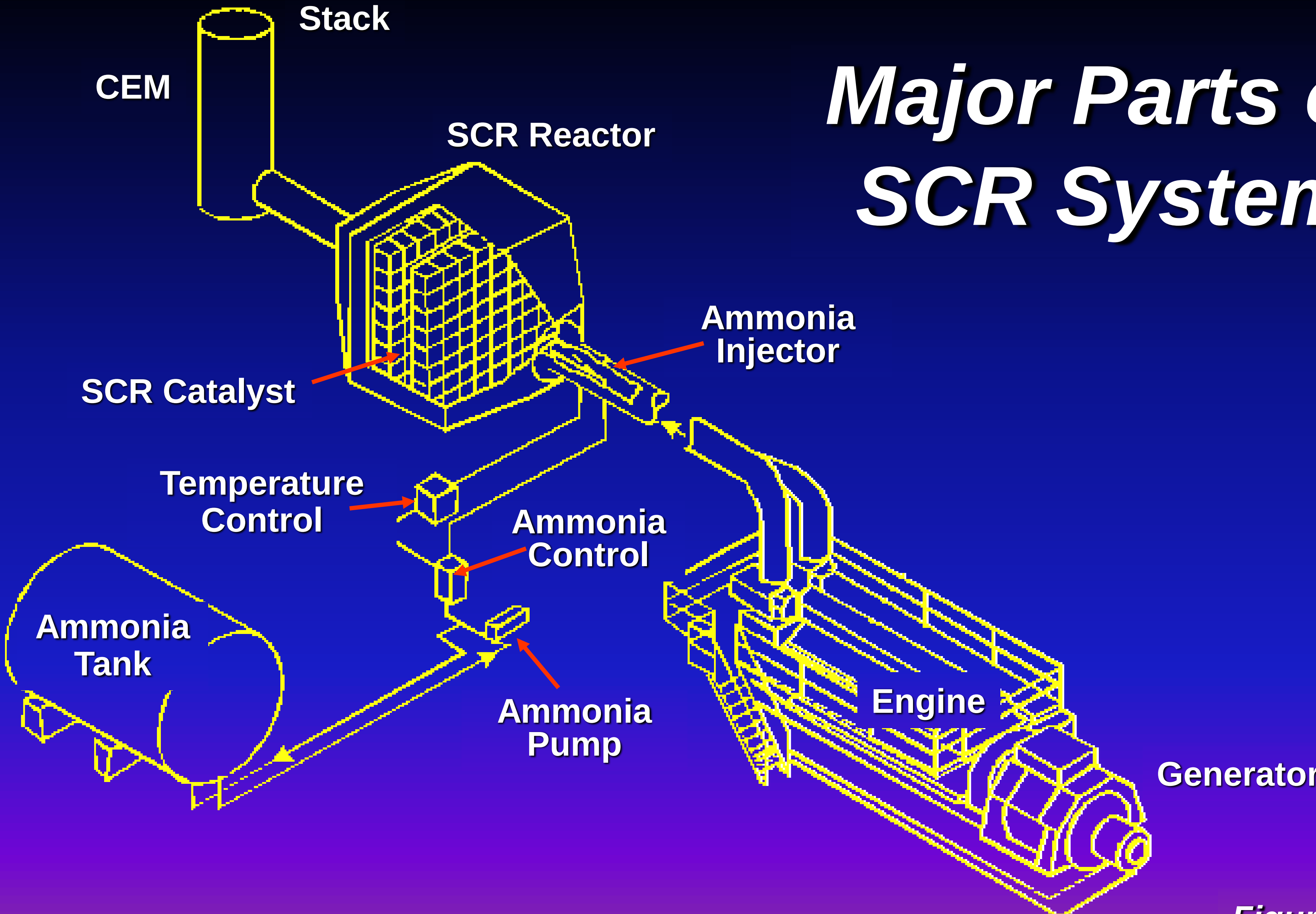
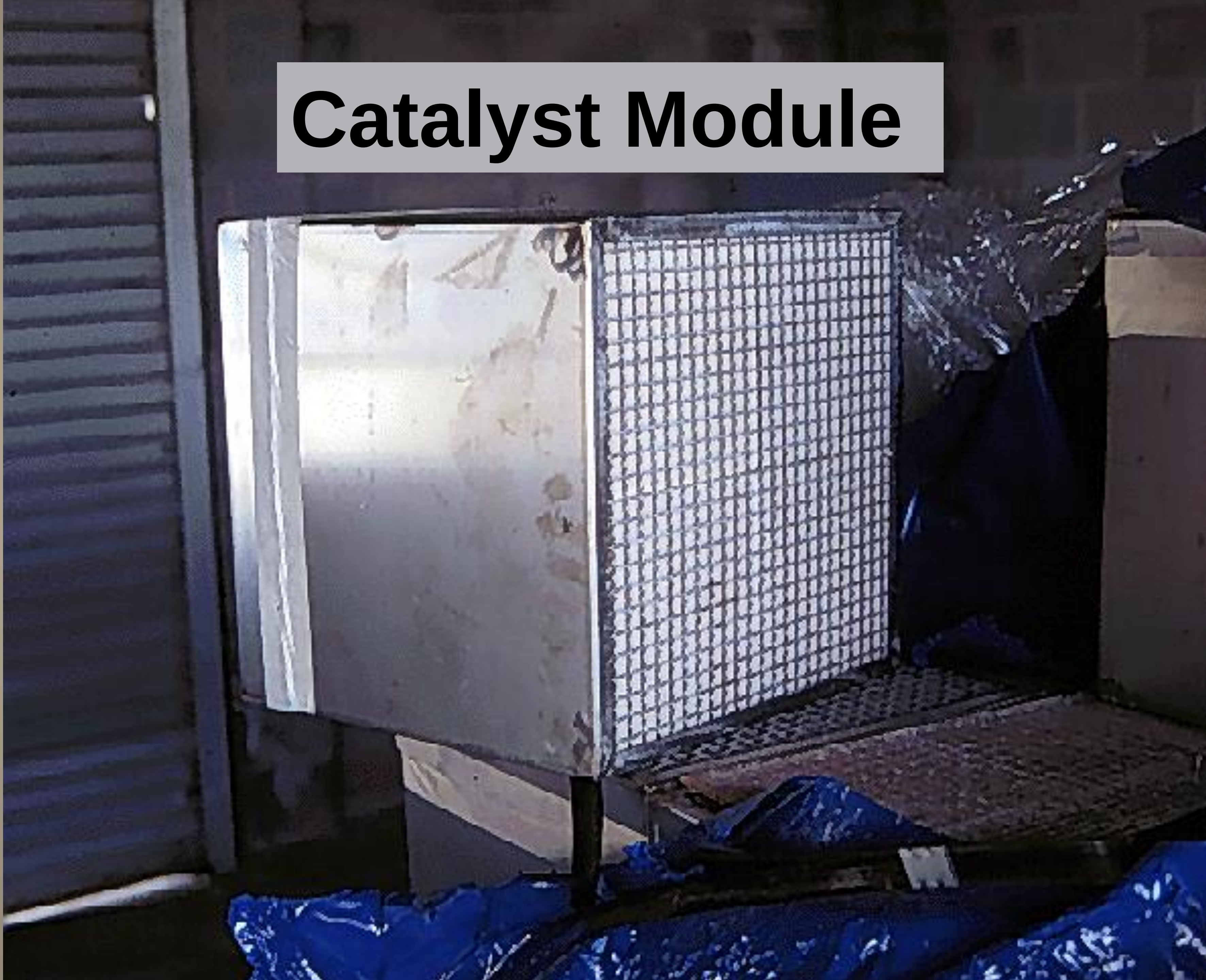
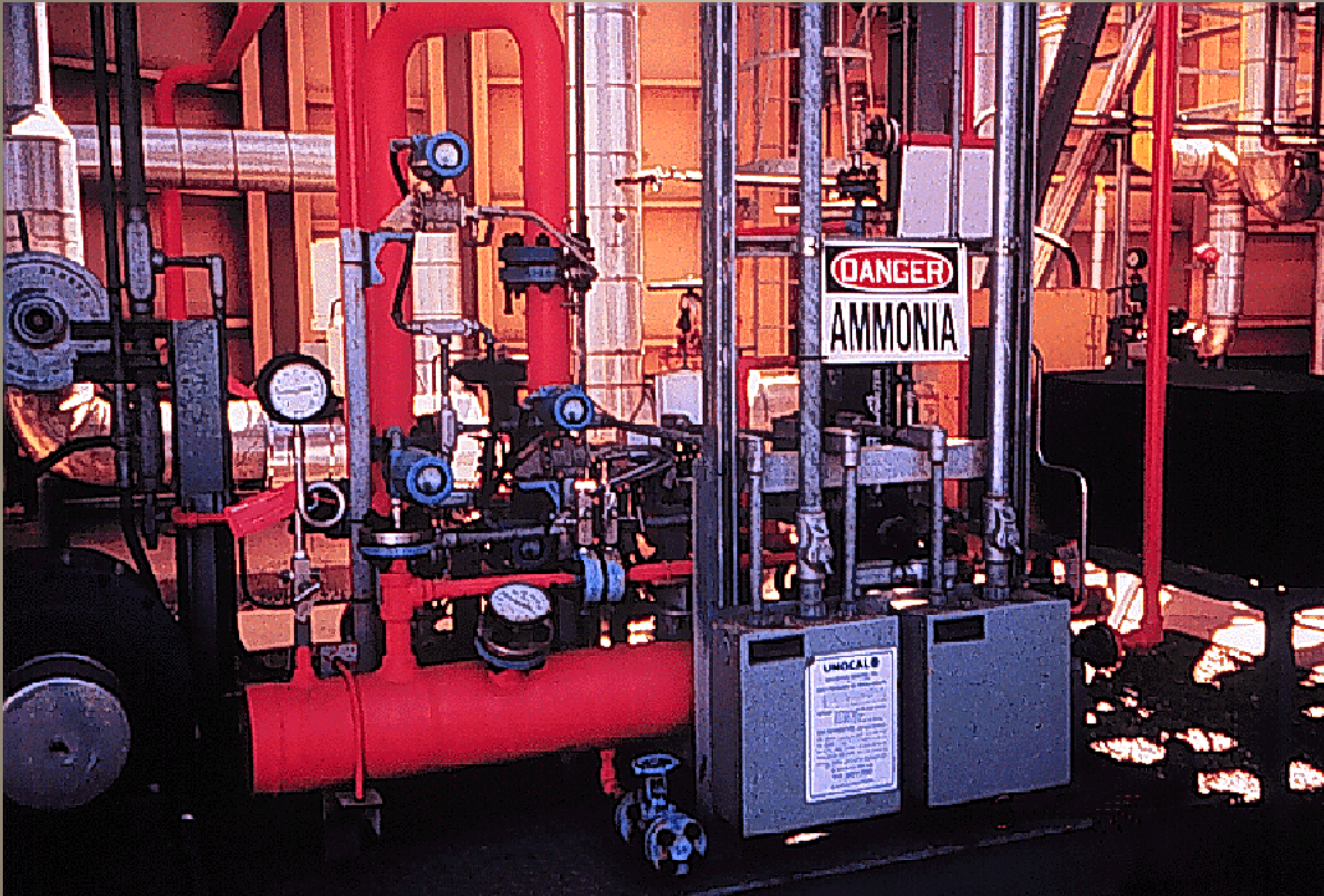


Figure 304.7

SCR Catalyst

Catalyst Module




DANGER
AMMONIA
UNOCAL


JLG LIFT

SCR System on Gas Turbine

% NOx removed vs. Vanadium Pentoxide Catalyst Temperature

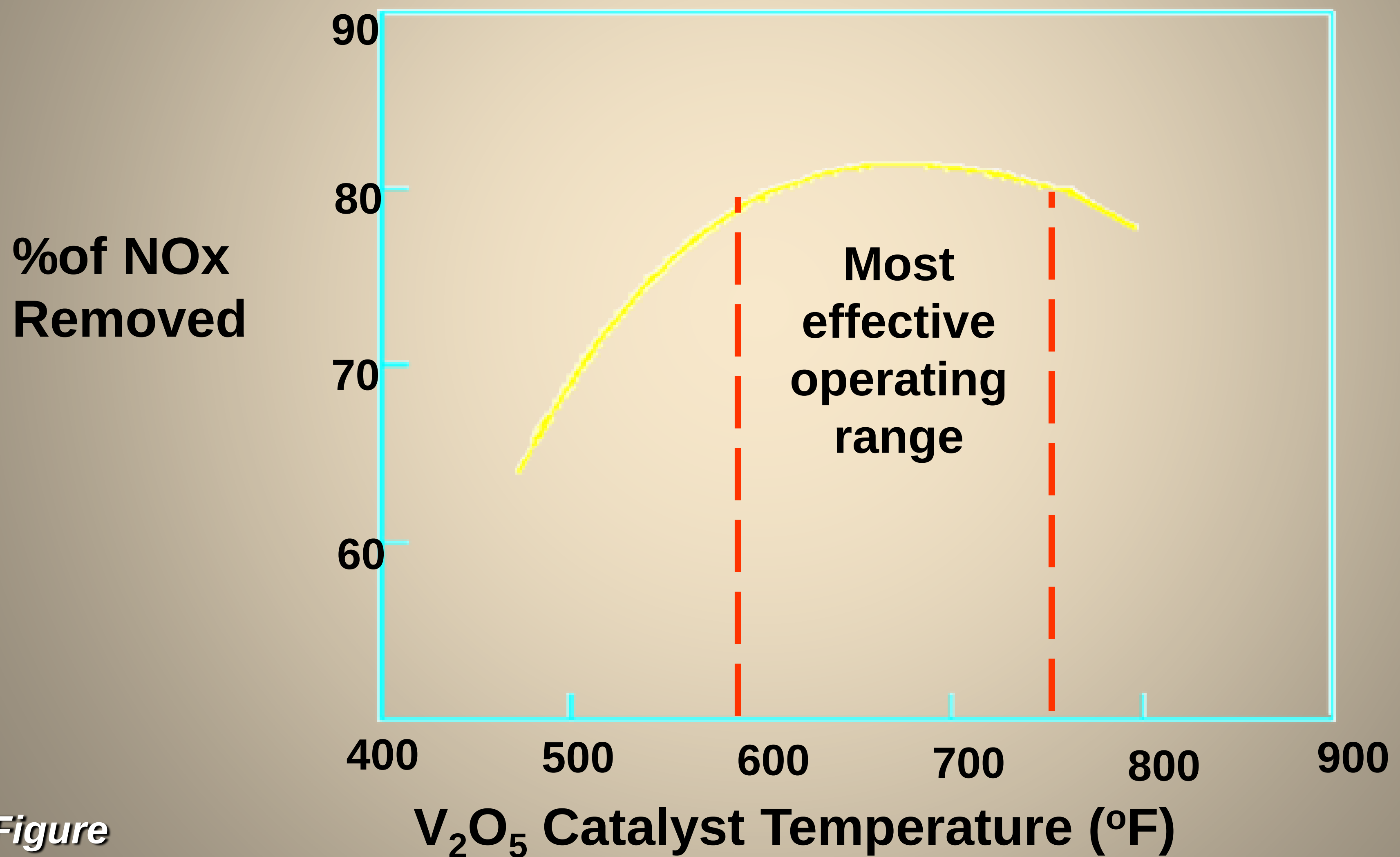


Figure 304.8

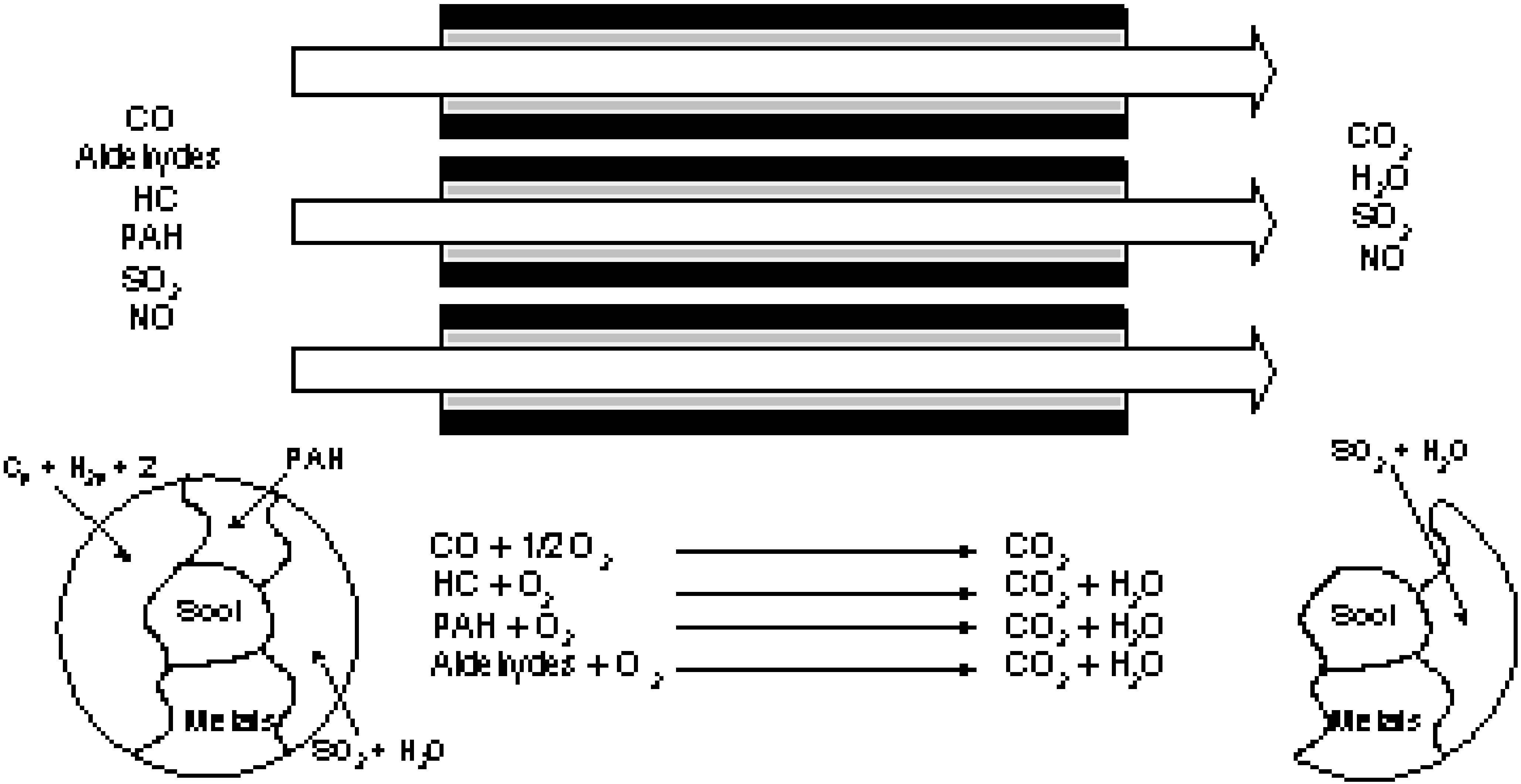
Selective Catalytic Reduction (SCR)

- 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 Two Way Catalyst (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)



$$CO + 1/2\,O_2 \longrightarrow CO_2$$
$$HC + O_2 \longrightarrow CO_2 + H_2O$$
$$PAH + O_2 \longrightarrow CO_2 + H_2O$$
$$\text{Aldehydes} + O_2 \longrightarrow CO_2 + H_2O$$

Particulate reduced by attacking SOF

Diesel Particulate Filter (DPF)

- *Collection of PM on filter with exhaust gas flow-through*
- *Regeneration required*
  - High exhaust temperature (600 - 650 ^{o}C)
  - Catalytic oxidation of particulate (~375 ^{o}C)
  - Oxidize NO to NO2 → adsorbs → reduces regeneration temperature
  - Fuel-borne catalyst
  - Ceramic coatings
  - Engine adjustments

Diesel Particulate Filter

Exhaust In

Exhaust Out


REGULATIONS

Regulations Affecting Stationary Engines

<u>RICE NESHAP</u>

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

<u>CI/SI ICE NSPS</u>

- 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 its40 CFR 1068.30function
- ...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

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

- 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, 2006
  - Modified or reconstructed after July 11, 2005

SI ICE NSPS

- 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

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

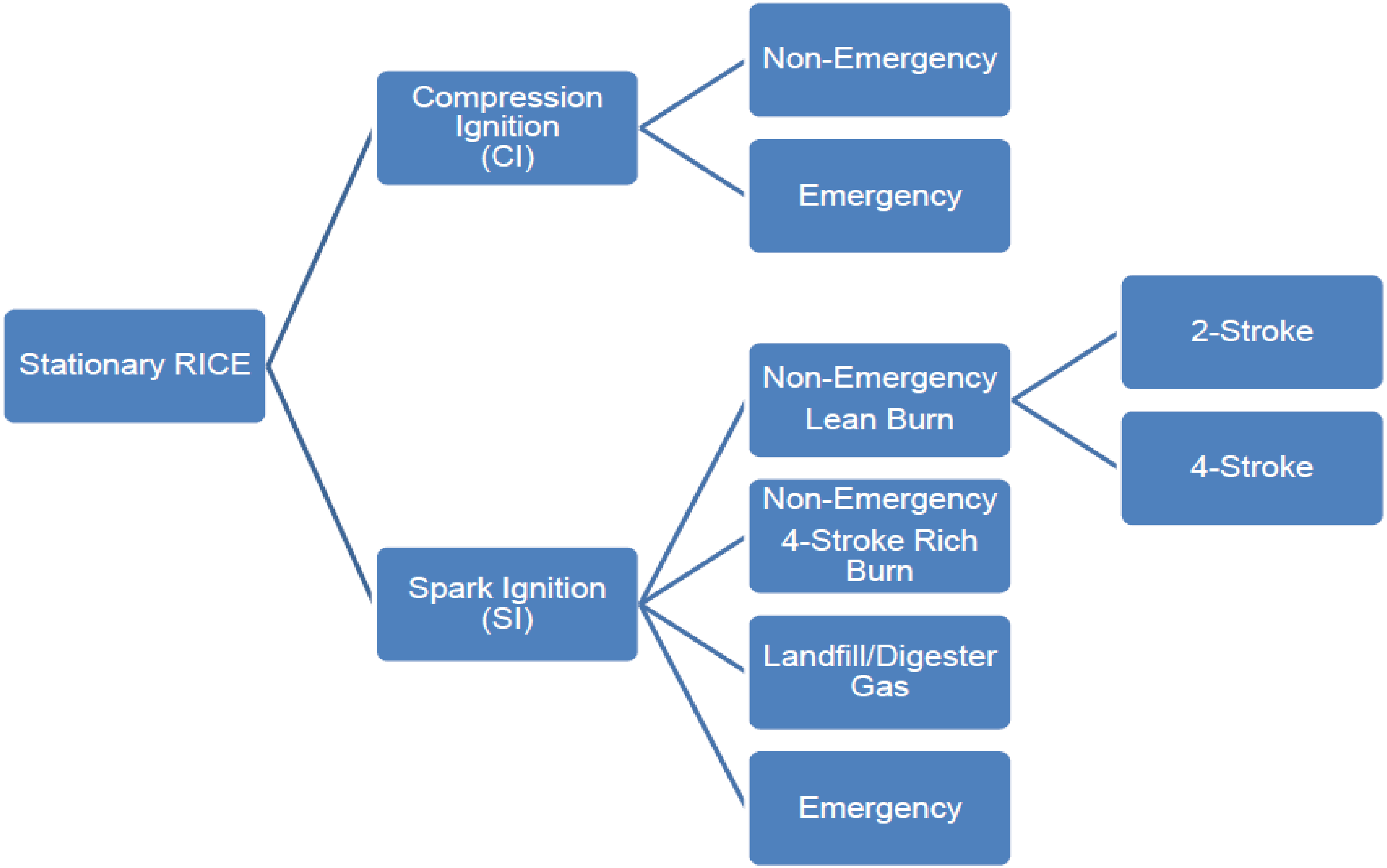
- Reconstruction
  - Replacement of components of an existing facility to such an extent that the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable entirely new facility, and it is technologically and economically feasible to meet the applicable standards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

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

- <u>Determining construction date</u>: 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

Emission Standards: Existing RICE at Major Sources

<table>
<tr><th rowspan="3">HP</th><th colspan="6">Engine Subcategory</th></tr>
<tr><th colspan="5">Non-emergency</th><th rowspan="2">Emergency</th></tr>
<tr><th>CI</th><th>SI 2SLB</th><th>SI 4SLB</th><th>SI 4SRB</th><th>SI LFG/DG</th></tr>
<tr><td><100</td><td colspan="5">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 rowspan="3">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</td></tr>
<tr><td>100-300</td><td>230 ppm CO</td><td rowspan="2">225 ppm CO</td><td rowspan="2">47 ppm CO</td><td rowspan="2">10.3 ppm CH_2O</td><td rowspan="2">177 ppm CO</td></tr>
<tr><td>300-500</td><td>49 ppm CO or 70% CO reduction</td></tr>
<tr><td>>500</td><td>23 ppm CO or 70% CO reduction</td><td>No standards</td><td>No standards</td><td>350 ppb CH_2O or 76% CH_2O reduction</td><td>No standards</td><td>No standards</td></tr>
</table>

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.

Emission Standards – New RICE at Major Sources

<table>
<tr><th rowspan="3">HP</th><th colspan="6">Engine Subcategory</th></tr>
<tr><td colspan="5">Non-emergency</td><td rowspan="2">Emergency</td></tr>
<tr><td>CI</td><td>SI 2SLB</td><td>SI 4SLB</td><td>SI 4SRB</td><td>SI LFG/DG</td></tr>
<tr><td><250</td><td rowspan="2">Comply with CI NSPS</td><td rowspan="2">Comply with SI NSPS</td><td>Comply with SI NSPS</td><td rowspan="2">Comply with SI NSPS</td><td rowspan="2">Comply with SI NSPS</td><td rowspan="2">Comply with CI/SI NSPS</td></tr>
<tr><td>250-500</td><td rowspan="2">14 ppm CH_2O or 93% CO reduction</td></tr>
<tr><td>>500</td><td>580 ppb CH_2O or 70% CO reduction</td><td>12 ppm CH_2O or 58% CO reduction</td><td>350 ppb CH_2O or 76% CH_2O reduction</td><td>No standards</td><td>No standards</td></tr>
</table>

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

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	•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) Existing non-emergency CI >300 HP: •Ultra low sulfur diesel (ULSD) •Crankcase emission control requirements

Compliance Requirements: RICE at Major Sources

Engine Subcategory	Compliance Requirements
Existing non-emergency: •SI 4SRB >500 HP at major source New non-emergency: •SI 2SLB >500 HP at major source •SI 4SLB >250 HP at major source •SI 4SRB >500 HP at major source •CI>500 HP at major source	•Initial emission performance test •Subsequent performance testing semiannually (can reduce frequency to annual)* •Operating limitations - catalyst pressure drop and inlet temperature •Notifications •Semiannual compliance reports
•New emergency/limited use >500 HP at major source	•Initial notification •Reporting and ULSD for emergency engines used for emergency demand response
•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 4SRB engine complying with formaldehyde % reduction standard only if engine is ≥5,000 HP

Compliance Requirements: RICE at Major Sources

Engine Subcategory	Compliance Requirements
•Existing emergency/black start ≤500 HP at major source •Existing non-emergency <100 HP at major source	•Operate/maintain engine & control device per manufacturer's instructions or owner-developed maintenance plan •May use oil analysis program instead of prescribed oil change frequency •Emergency engines must have hour meter and record hours of operation •Keep records of maintenance •Notifications not required •Reporting and ULSD for emergency engines >100 HP used for emergency demand response

Emission Standards: Existing Non-Emergency RICE at Area Sources

<table>
<tr><th rowspan="3">HP</th><th colspan="5">Engine Subcategory</th></tr>
<tr><td colspan="5">Non-emergency</td></tr>
<tr><td>CI</td><td>SI 2SLB</td><td>SI 4S in remote areas</td><td>SI 4S not in remote areas</td><td>SI LFG/DG</td></tr>
<tr><td>≤300</td><td>Change oil/filter & inspect air cleaner every 1,000 hours or annually; inspect hoses/belts every 500 hours or annually</td><td rowspan="3">Change oil/filter, inspect spark plugs, & inspect hoses/ belts every 4,320 hours or annually</td><td colspan="2" rowspan="2">Change oil/ filter, inspect spark plugs, & inspect hoses/belts every 1,440 hours of operation or annually</td><td rowspan="3">Change oil/ filter, inspect spark plugs, & inspect hoses/ belts every 1,440 hours of operation or annually</td></tr>
<tr><td>300-500</td><td>49 ppm CO or 70% CO reduction</td></tr>
<tr><td>>500</td><td>23 ppm CO or 70% CO reduction</td><td>Change oil/ filter, inspect spark plugs, & inspect hoses/belts every 2,160 hours of operation or annually</td><td>If engine used >24 hrs/yr:

4SLB: Install oxidation catalyst

4SRB: Install NSCR</td></tr>
</table>

New Non-Emergency RICE Located at Area Sources: meet Stationary Engine NSPS

- part 60 subpart IIII if CI; part 60 subpart JJJJ if SI

Compliance Requirements: Non-Emergency Engines at Area Sources

Engine Subcategory	Compliance Requirements
•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 4SLB/4SRB >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

Compliance Requirements: Non-Emergency Engines at Area Sources

Engine Subcategory	Compliance Requirements
Existing non-emergency: •black start at area source •CI ≤300 HP at area source •SI ≤500 HP at area source •SI 2SLB >500 HP at area source •SI LFG/DG >500 HP at area source •SI 4SLB/4SRB >500 HP at area source used ≤24 hours/year or in remote area	•Operate/maintain engine & control device per manufacturer's instructions or owner-developed maintenance plan •May use oil analysis program instead of prescribed oil change frequency •Keep records of maintenance •Notifications not required

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 (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

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

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

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

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

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

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 (U.S. Manufacturer or Importer) **Certificate Number:** CPKXL04.4NJ1-007	**Effective Date:** 09/02/2011 **Expiration Date:** 12/31/2012	Karl J. Simon, Director Compliance and Innovative Strategies Division	**Issue Date:** 09/02/2011 **Revision Date:** N/A

Model Year: 2012
Manufacturer Type: Original Engine Manufacturer
Engine Family: CPKXL04.4NJ1

Mobile/Stationary Indicator: Stationary
Emissions Power Category: 75<=kW<130
Fuel Type: Non-Standard Fuel, Diesel
After Treatment Devices: No After Treatment Devices Installed
Non-after Treatment Devices: Electronic Control

Pursuant to Section 111 and Section 213 of the Clean Air Act (42 U.S.C. sections 7411 and 7547) and 40 CFR Part 60, and subject to the terms and conditions prescribed in those 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 CFR Part 60 and produced in the stated model year.

This certificate of conformity covers only those new compression-ignition engines which conform in all material respects to the design specifications that applied to those engines described in the documentation required by 40 CFR Part 60 and which are produced during the model year stated on this certificate of the said manufacturer, as defined in 40 CFR Part 60.

It is a term of this certificate that the manufacturer shall consent to all inspections described in 40 CFR 1068 and authorized in a warrant or court order. Failure to comply with the requirements of such a warrant or court order may lead to revocation or suspension of this certificate for reasons specified in 40 CFR Part 60. It is also a term of this certificate that this certificate may be revoked or suspended or rendered void *ab initio* for other reasons specified in 40 CFR Part 60.

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.

Owner/Operator Compliance Requirements

- 2007 model year and later with displacement <30 liters/cylinder*
  - purchase <u>certified</u> 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)

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

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% O_2 standards for some engines
- Pollutants: NOx, CO, VOC
- Some standards modeled after EPA's standards for nonroad SI engines

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

Compliance Requirements for Owners/Operators

- <u>Certified engines</u>
  - 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
    - $100 \le HP \le 500$ – 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≤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

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
	IL, IN	Nathan Frank	(312) 886-3850	frank.nathan@epa.gov
	WI, MI	Sara Breneman	(312) 886-0243	breneman.sara@epa.gov
	OH, MN	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

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

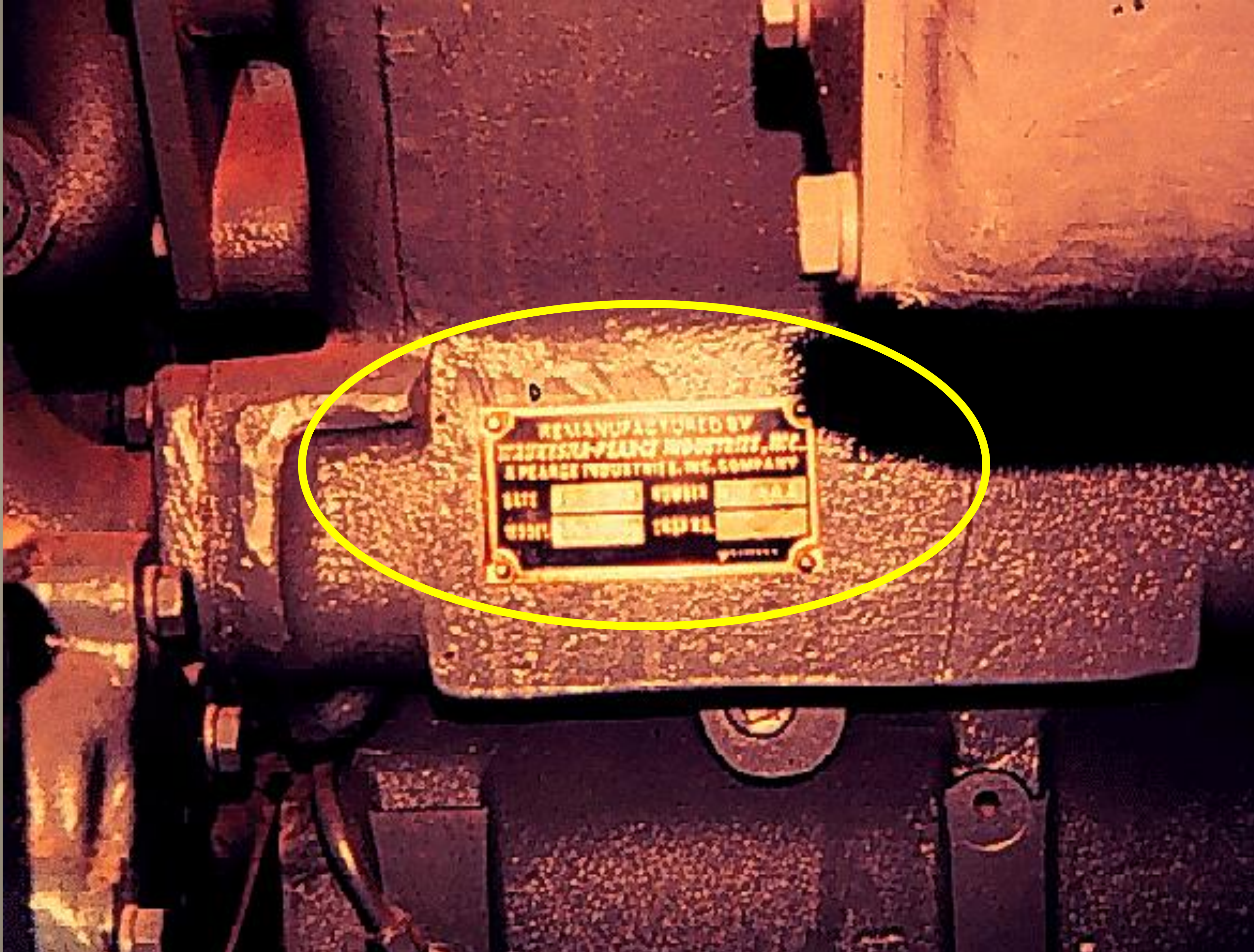
- Fuels
- Hours of operation
- Emission limits
- Emission control equipment
- Recordkeeping
- CEMs

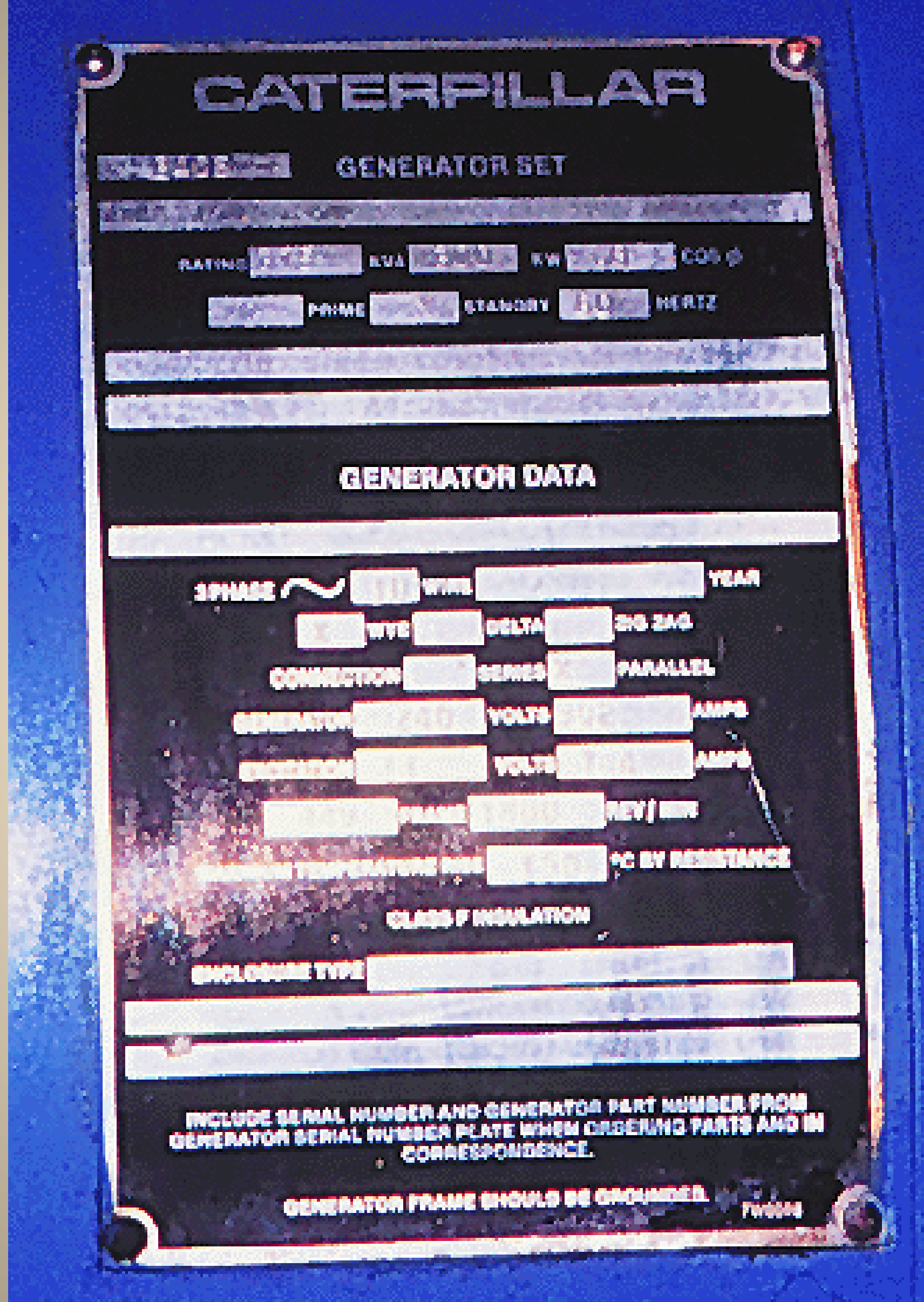
Inspection

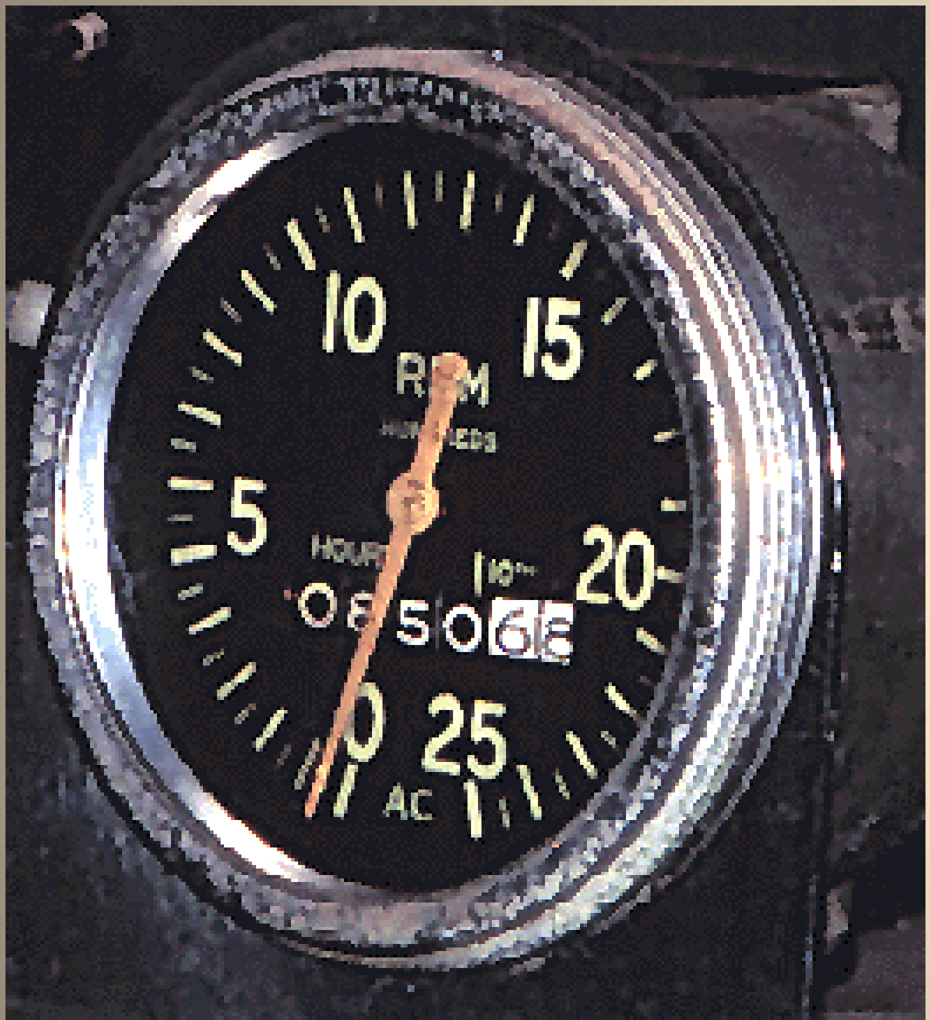
- Visible Emissions Evaluation
- General Upkeep and Maintenance
- Monitoring Instruments (operation, records)
- Fuel Type, Quality (records, samples)
- Control Devices
- Maintenance Records

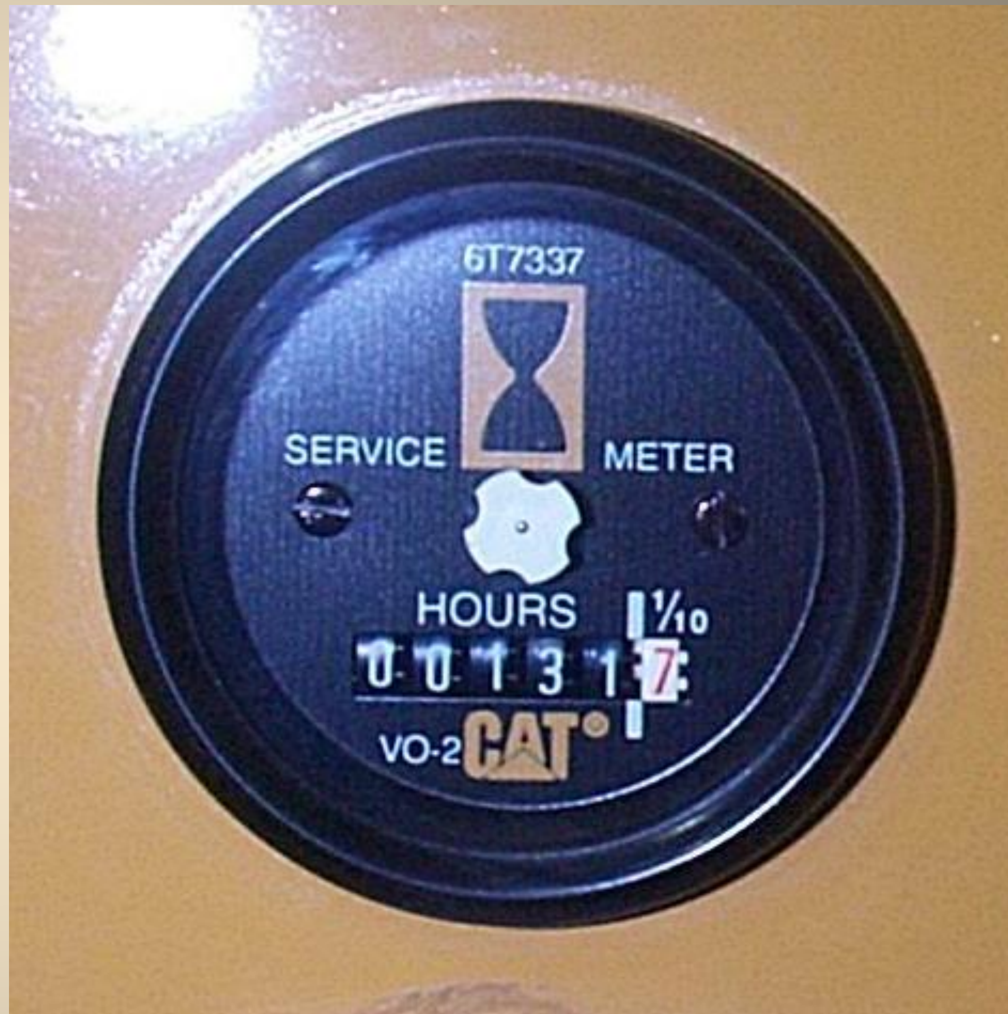
Inspection (con't.)

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


REMANUFACTURED BY


CATERPILLAR
GENERATOR SET
RATING
KVA
KW
COS ϕ
PRIME
STANDBY
HERTZ
GENERATOR DATA
3 PHASE
WIRE
YEAR
WYE
DELTA
ZIG ZAG
CONNECTION
SERIES
PARALLEL
GENERATOR
VOLTS
AMPS
VOLTS
AMPS
FRAME
REV / MIN
TEMPERATURE RISE
°C BY RESISTANCE
CLASS F INSULATION
ENCLOSURE TYPE
INCLUDE SERIAL NUMBER AND GENERATOR PART NUMBER FROM GENERATOR SERIAL NUMBER PLATE WHEN ORDERING PARTS AND IN CORRESPONDENCE.
GENERATOR FRAME SHOULD BE GROUNDED.

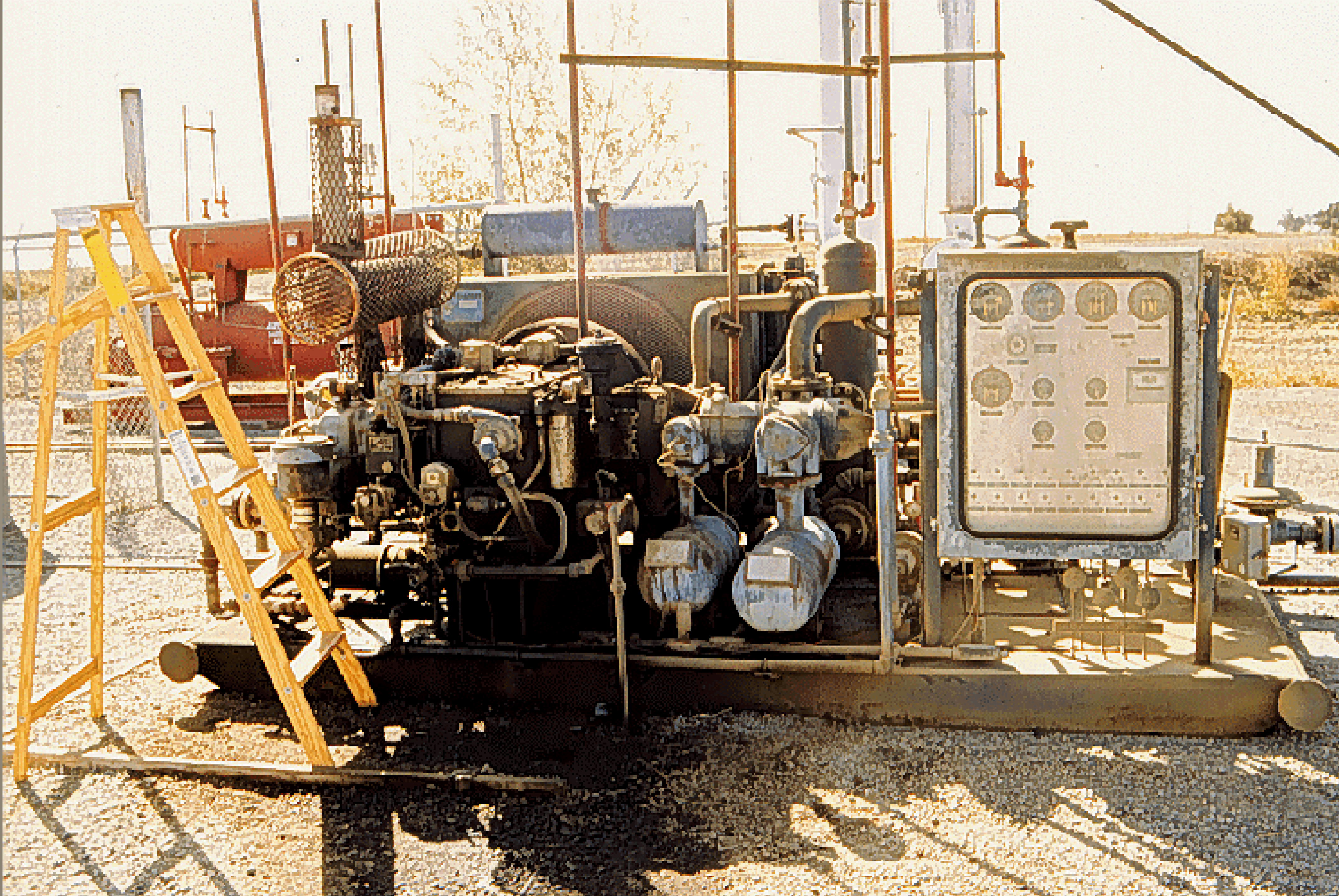

10
15
5
20
25
HOURS
AC


6T7337
SERVICE
METER
HOURS
1/10
VO-2
CAT


10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
9000
8000
7000
6000
5000
4000
3000
2000
1000
E
F
NEUMERCATOR


CATERPILLAR
083
DEGREES F
ENGINE OIL
ENGINE COOLANT
PSID
OIL FILTER DIFFERENTIAL
PSID
ENGINE COOLANT DIFFERENTIAL
ENGINE OIL


GEN
5




GAS INLET
AMB TEMP
GAS TEMP
LAND
F1
F2
F3
F4
LANCOM
MODEL 6500

SAFETY SAFETY

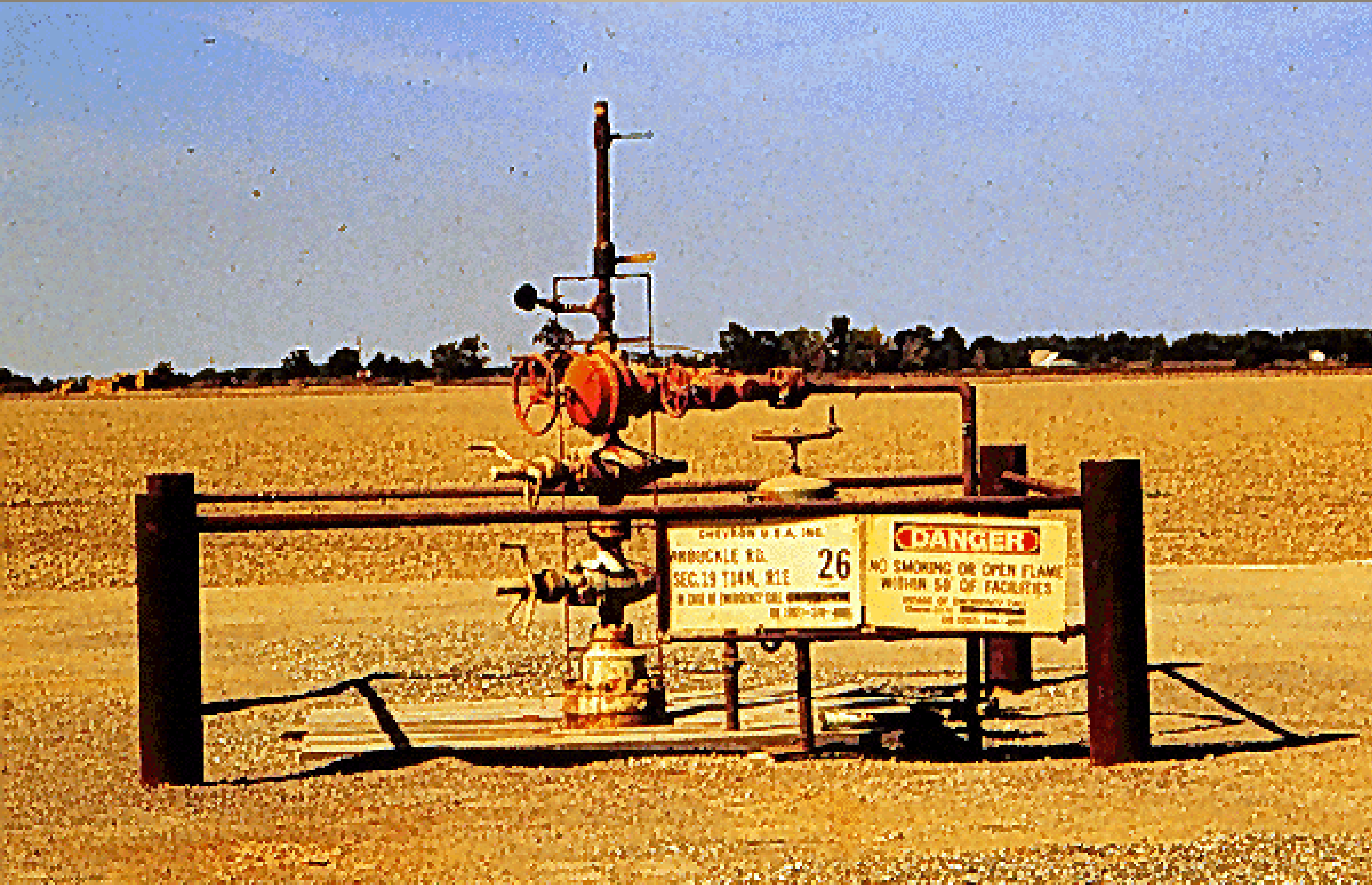
SAFETY SAFETY

SAFETY

SAFETY SAFETY

SAFETY SAFETY


CAUTION
DO NOT OPEN DOOR
WITHOUT BYPASSING
FIRE DETECTION SYSTEM
CAUTION
HEARING PROTECTION
REQUIRED WHEN DOOR OPEN
CAUTION
HOT INSIDE
CAUTION
LOCK OUT FIRE SYSTEM
PRIOR TO ENTERING
ENCLOSURE.


26
DANGER
NO SMOKING OR OPEN FLAME
WITHIN 50 OF FACILITIES

FURTHER INFORMATION

- EPA stationary engine page: https://www.epa.gov/stationary-engines
- https://www.epa.gov/stationary-engines/guidance-and-tools-implementing-stationary-engine-requirements - Regulatory Navigation Interactive Tools and Regulatory summary pages
- www.combustionportal.org


FINISH