UT-BATTELLE

# Overview of Fuels, Engines, and Emissions Research at ORNL

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**Fuels, Engines, and Emissions Research Center (FEERC)**

**Oak Ridge National Laboratory**

**ORNL Day of Science**

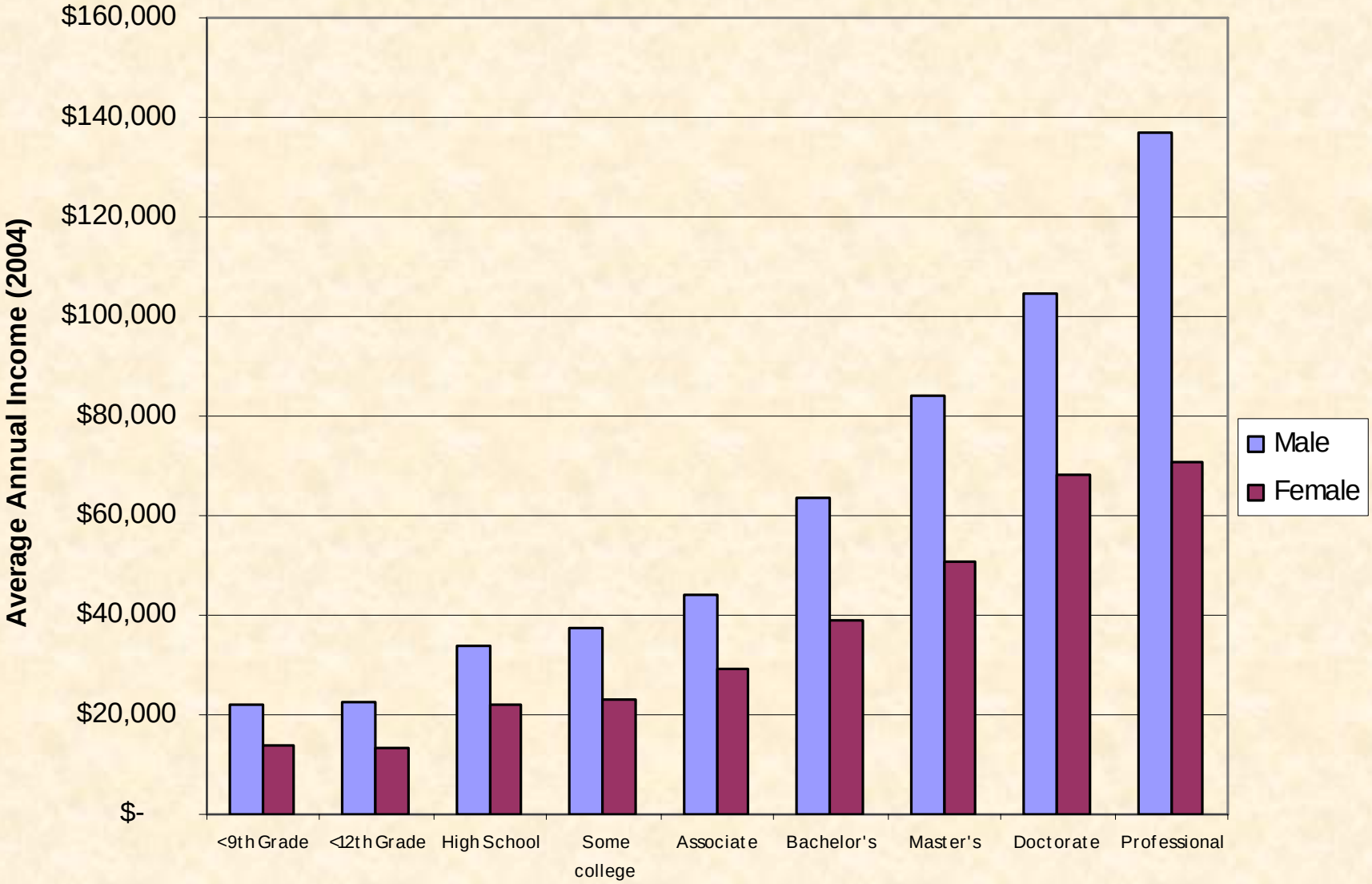
**October 16, 2006**

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

# Realizing Your Full Potential

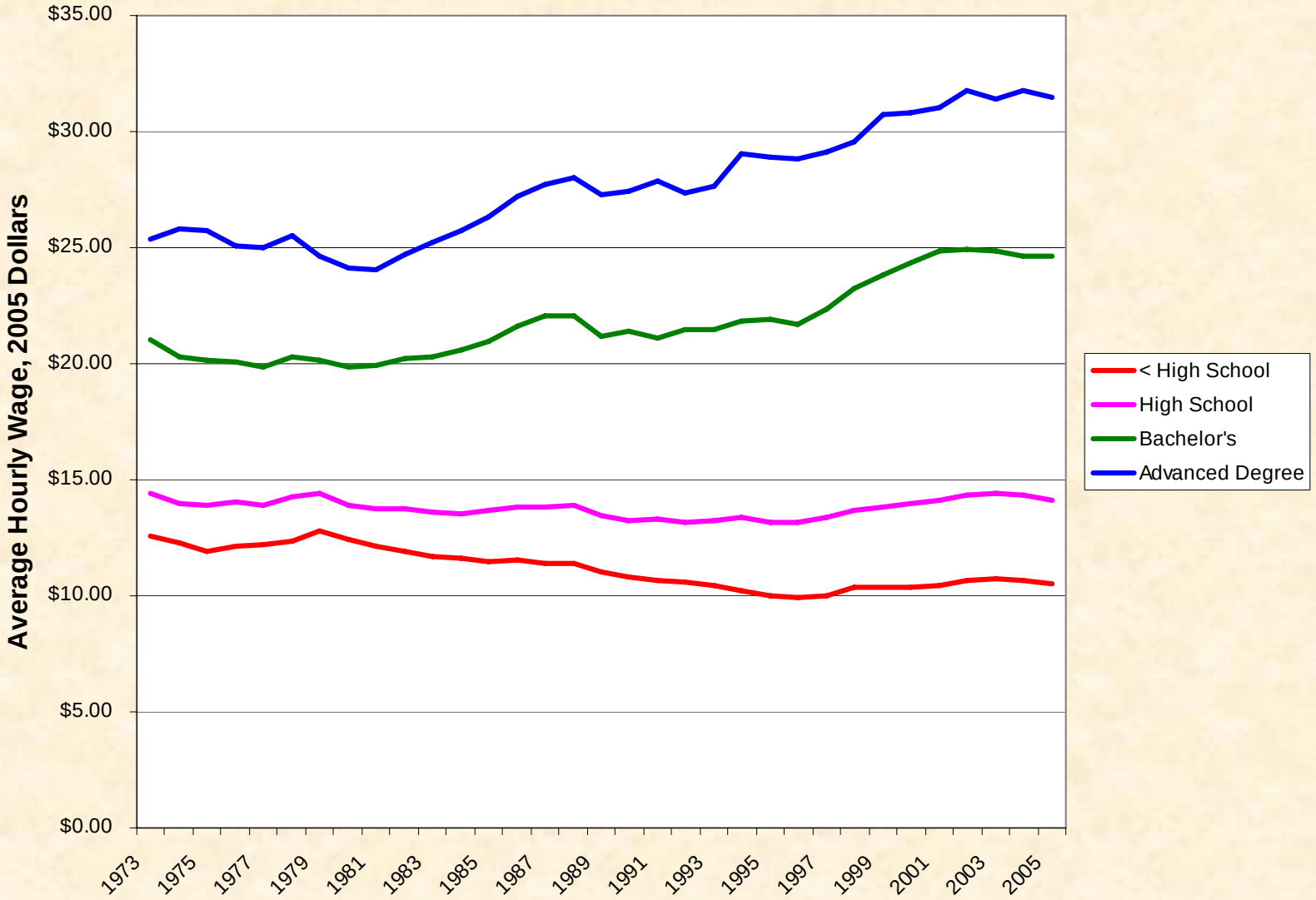
- **Having an advanced degree (i.e., Master's or Ph.D.) can really pay dividends**
- **Globalization affects professional careers, not just blue collar workers**
- **Don't think that your education is over after you graduate**

# Impact of Education on Earnings




Source: MSN Encarta / U.S. Census Bureau

# Trends of Income Differential




Source: Economic Policy Institute

# Globalization

- **Increasingly, the engineering environment is a global one**
  - **Product development in Mexico**
  - **Software development in India**
  - **Research in China**
- **Engineering tasks easily "off-shored"**
  - **Routine, easily documented activities**
  - **Far removed from customer**
  - **Relatively self-contained, with little organizational interaction required**
- **Realize that businesses pay for value received**
  - **The value you provide must surpass the value that can be obtained elsewhere**

# Continuing Education

- **Attaining an advanced degree is a significant accomplishment**
  - **Don’t rest on your laurels**
  - **Be prepared to learn your entire career**
- **Types of ongoing learning opportunities**
  - **Additional College Classes**
  - **Company-Specific Training**
  - **Off-Site Professional Development**
  - **Web Seminars**
- **Make it a goal to improve your skills each and every year**
  - **Avoid obsolescence**
  - **Maintain interest and enthusiasm**
  - **Open new opportunities**

# Oak Ridge National Laboratory

Mission: Conduct basic and applied research and development to create scientific knowledge and technological solutions

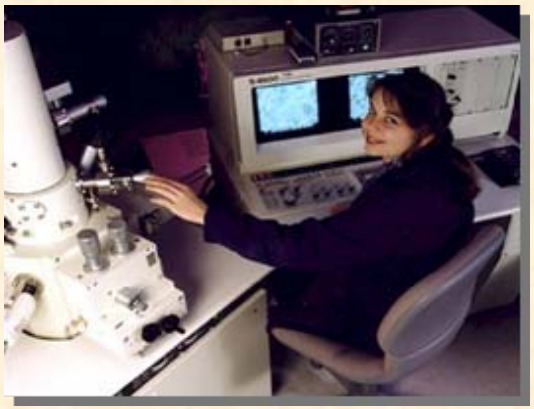
- **Beginnings in the Manhattan Project**
- **Isotope production one of greatest impacts on society**
- **DOE's largest multi-program science lab**
- **Nation's largest energy R&D lab**
- **4.4 million square feet of facilities**
- **3,700 staff**
- **$1 billion annual budget**

# ORNL Science and Engineering Professional Staff

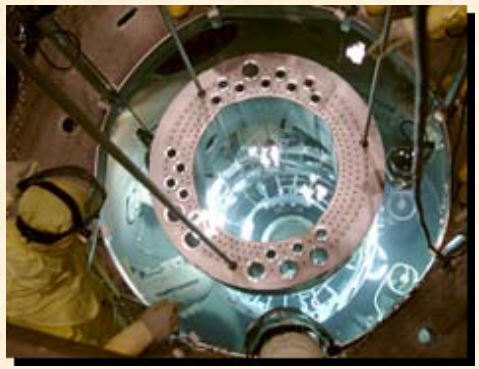
- **By Degree Level**

| | |
|---|---|
| **Bachelors** | **301** |
| **Masters** | **362** |
| **Ph.D.** | **722** |

# ORNL's major facilities for research



High Temperature
Materials Laboratory



High Flux
Isotope Reactor

National
Environmental
Research Park

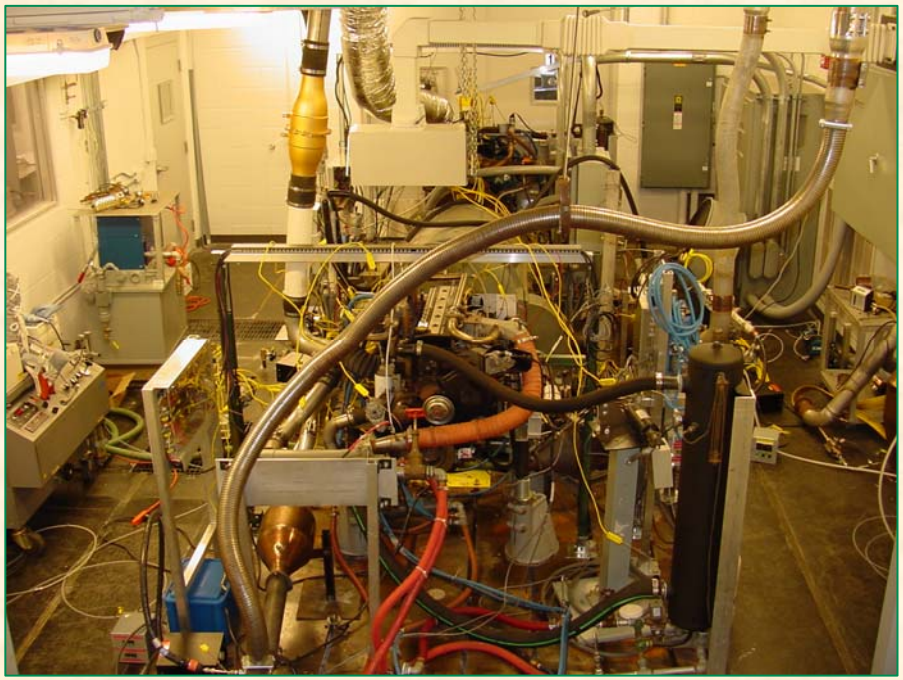

National Transportation
Research Center

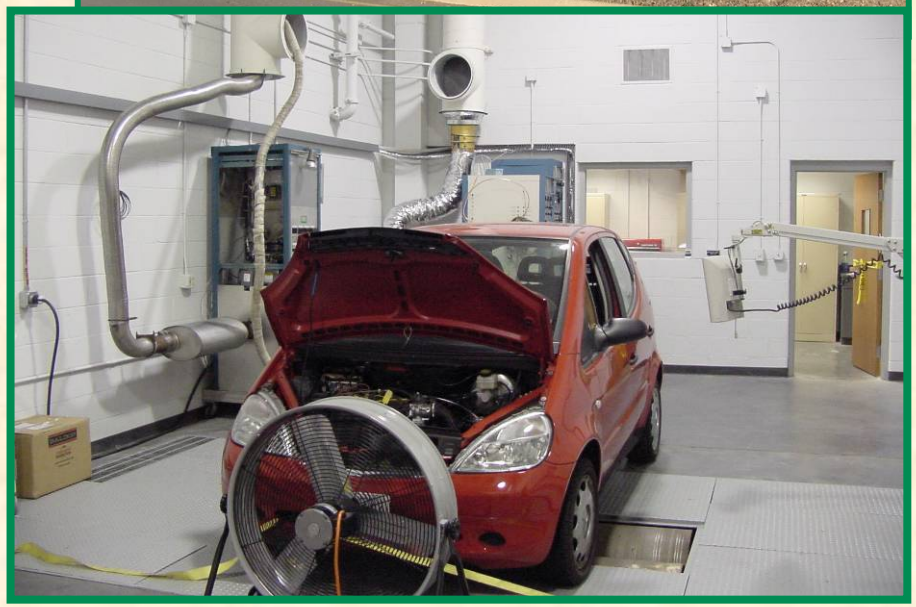

Center for Nanophase Materials Sciences

Center for Computational Sciences

# NTRC Building in West Knoxville—Home for ORNL's Fuels, Engines, and Emissions Research Center

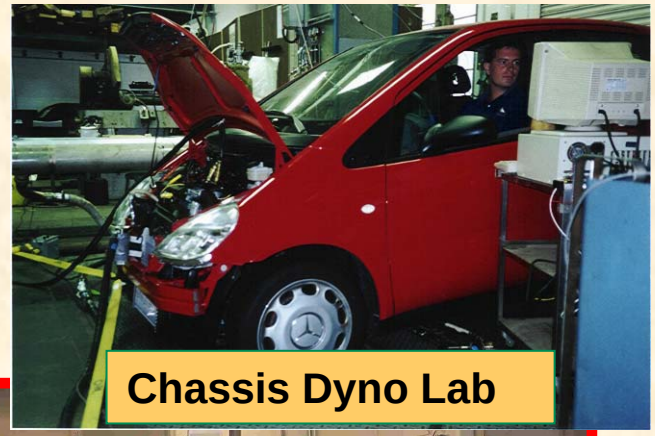
- **Facility jointly occupied with UT Transportation Center, Other ORNL Transportation Groups**
- **Lab facilities relocated from ORNL/Y-12 in 2001**
- **ORNL engine R&D began in 1983**

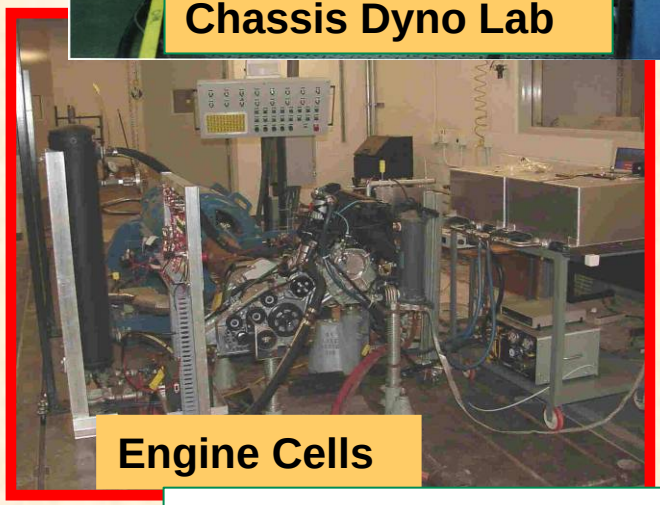





# Fuels, Engines, & Emissions Research Center.... A Comprehensive Laboratory for Energy Conversion Technologies

- **A DOE National User Facility in the NTRC**
- **Emphasis on unique or extraordinary diagnostic and analytical tools for energy conversion R&D**
- **R&D from bench-scale to vehicle**
  - **Chemical/analytical labs**
  - **6 dynamometer stands: 25-600 hp**
  - **Full-pass engine controls support research**
  - **Emissions analysis with high resolution of time and species**
  - **Non-invasive optical and mass-spec diagnostics**
  - **Modeling & simulation**




# DOE Energy Efficiency and Renewable Energy (EERE) mission and priorities set foundation for many FEERC projects

## Mission

**The EERE mission is to strengthen America's energy security, environmental quality, and economic vitality in public-private partnerships that:**

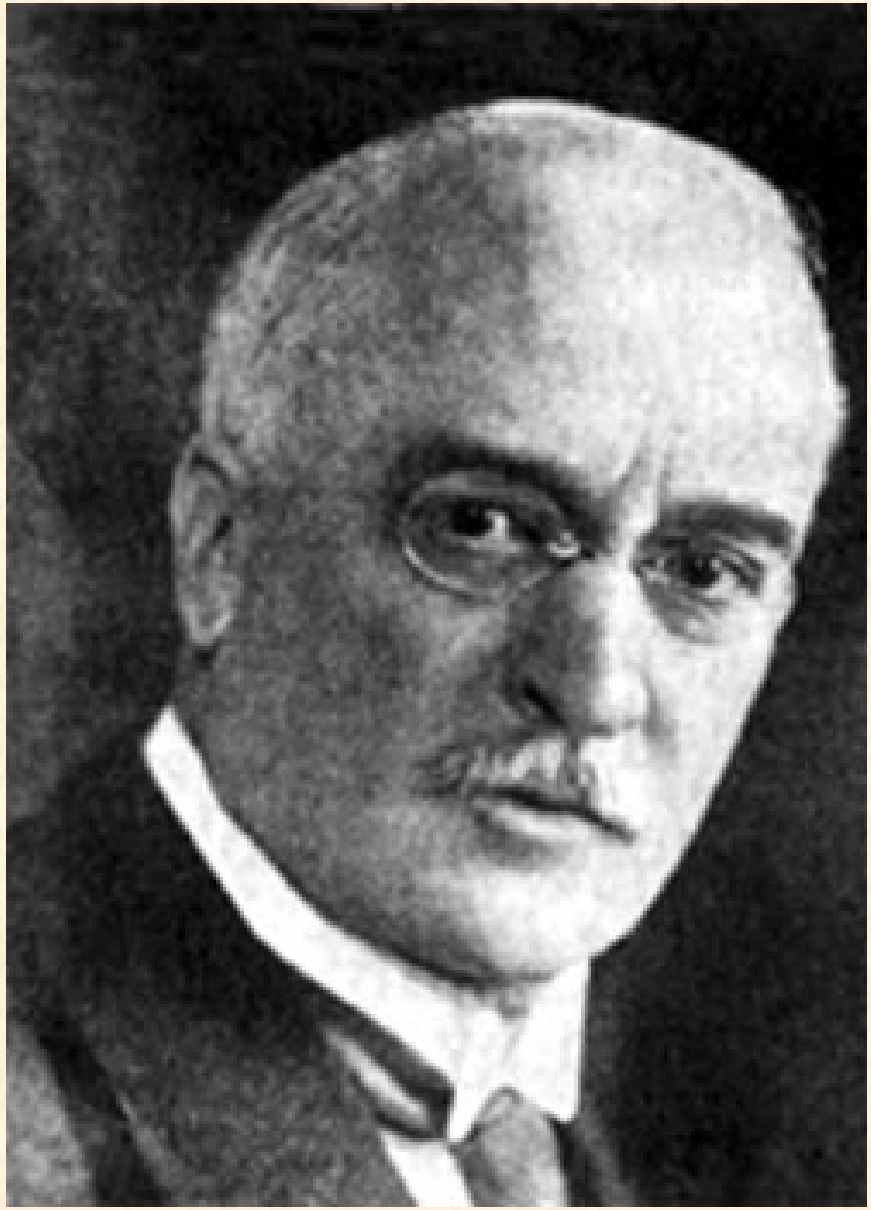
**Enhance energy efficiency and productivity;**

**Bring clean, reliable and affordable energy technologies to the marketplace; and**

**Make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.**

# Father of the diesel engine

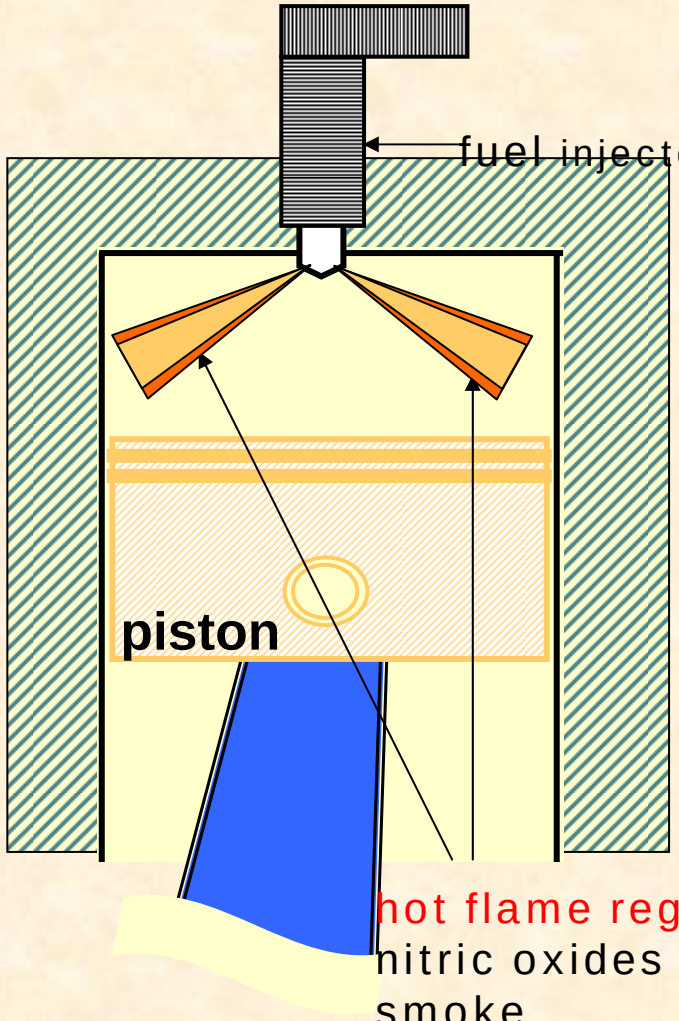
- **Rudolf Diesel 1858-1913**
- **Much more efficient than steam engines of the time**
- **Original vision – to run on coal dust and vegetable oils!**
  - **biodiesel isn't such a new idea**
- **Rags to riches to rags story**
  - **Died mysteriously on ferry to England 1913**

# Basics of diesel and gasoline engine combustion

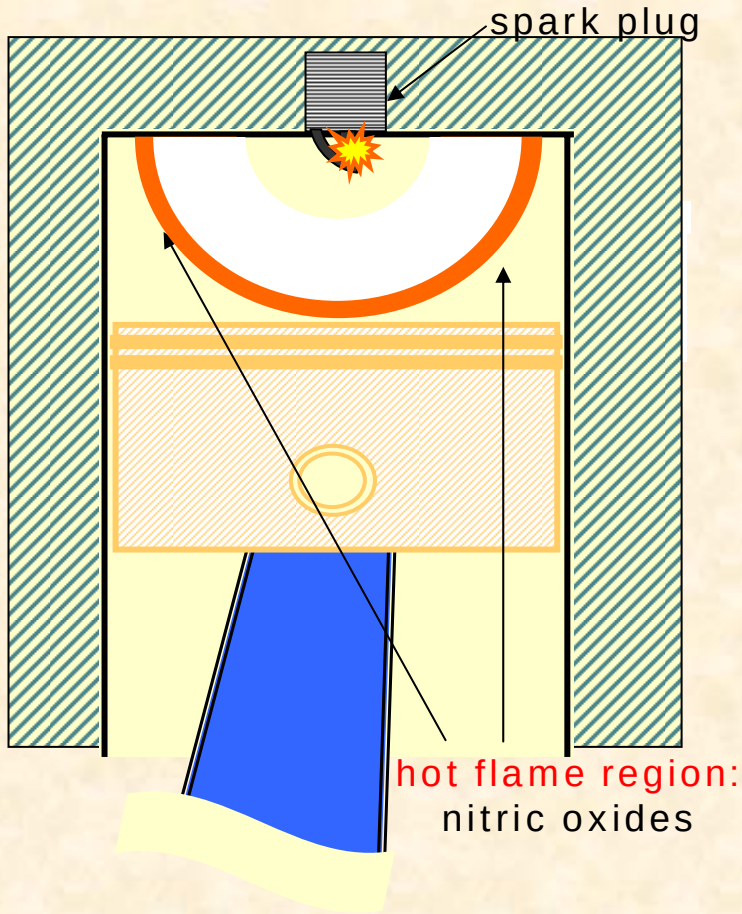
## Diesel Engine

(compression ignition
Lean, Stratified charge, Excess Oxygen
(Heterogeneous charge))




## Gasoline Engine

(spark ignition,
Homogeneous charge,
Stoichiometric (Chemically correct
air:fuel, no excess oxygen))

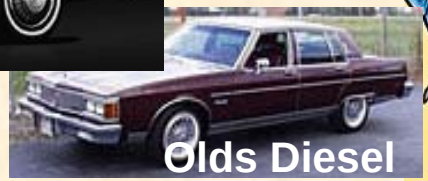



Courtesy of Caterpillar, 2003

# It is difficult for some folks to imagine a clean diesel....

# .... and difficult for many to imagine one they might want to own


1979 Cadillac Eldorado


Olds Diesel


"…the optional diesel version of the [V8] engine, …was rated at 125 horsepower and prone to catastrophic failure. The Olds-built diesel V8 was, quite simply, the worst piece of engineering ever foisted upon the Cadillac buying public... "

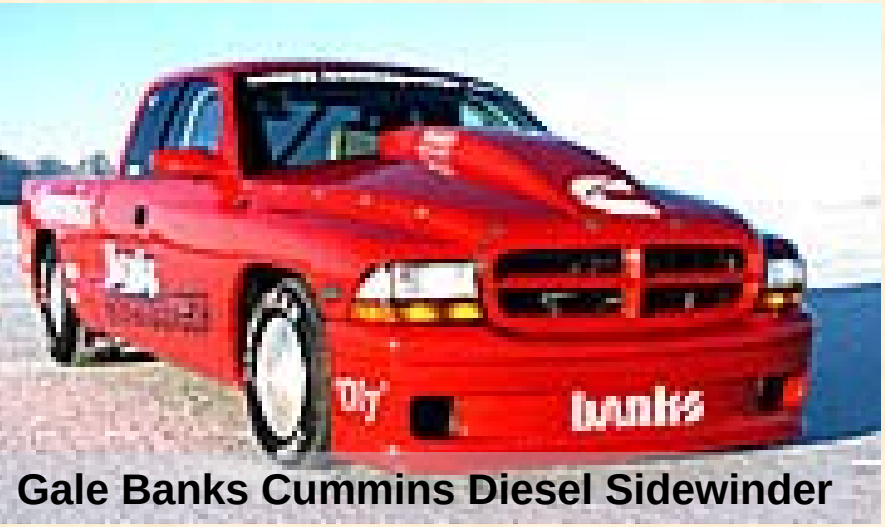
- John Pearley Huffman (www.edmunds.com)

"…Contrary to popular belief, the [Olds] engine was completely different than its gasoline brethren…The block was much sturdier… when cared for properly, ran for hundreds of thousands of miles…in the hands of an experienced diesel operator. ….it [also] makes a great gasoline race engine block."

- Randy Fish (www.popularhotrodding.com)

Fuel quality and lack of filtration led to demise of 1979-85 GM diesels

# But diesels can be fast, clean, durable, and efficient

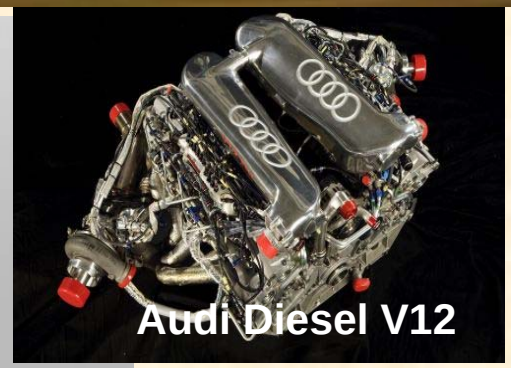


Gale Banks Cummins Diesel Sidewinder

Audi R10 diesel wins Le Mans

Mercedes E320 Bluetec


Honda Clean Diesel


Audi Diesel V12

# Diesel Emissions - Past, Present and Future

- **Some gasoline vehicles can already meet future emissions standards**
- **Emission control is key to expanded diesel use in U.S.!**
  - **Reduce Oil Imports**
  - **Reduce $CO_2$ emissions**
- **Diesel vehicles are 30% more fuel efficient than gasoline vehicles**
- **Must Maintain Efficiency Advantage of Diesel!**

Q:
Today's gasoline cars are equipped with catalytic converters and are very clean.

Why not use that technology on the diesel?

A:
*Stoichiometric* combustion allows use of Three-Way Catalyst to simultaneously *Oxidize* HC and CO while also *reducing* NOx

Excess Oxygen in *Lean* diesel exhaust precludes the use of this technology

# So what can be done about diesel emissions?
## Control options for NOx, HC, CO, and particle emissions

### Engine Technology (in-cylinder reductions)

- **Injection Pressure on the rise**
  - **Smaller holes, smaller droplets**
- **Exhaust Gas Recirculation (EGR)**
  - **Common in SI engines for years**
  - **New in light duty diesels circa 1999**
  - **New for HD diesels in 2002**

### Aftertreatment

- **NOx Control**
  - **Lean NOx trap (LNT) on light-duty diesels in 2007**
  - **Urea SCR likely for HD in 2010 (already in Europe)**
    - **Under consideration for light duty in U.S.**
- **HC/CO**
  - **Oxidation catalyst**
- **Particle (soot) emissions**
  - **Diesel particle filter**

What makes these catalyst technologies feasible is low sulfur fuel – coming to a pump near you in October 2006

# A project requested by another agency: FEERC research team responded to EPA need for data to support low-sulfur diesel fuel rulemaking (SAE 2001-01-1933)

Brian West, Scott Sluder

- **Provided early evidence that full diesel engine + aftertreatment system could achieve Tier2 emission levels**
- **Mercedes A-170 CIDI with exhaust gas recirculation and modern fuel system**
- **Prototype NOx adsorber catalyst and lab-constrained regeneration system**
- **Catalyzed soot filter**
- **Diesel fuel with 3 ppm sulfur**
- **Results cited in EPA diesel sulfur rulemaking**

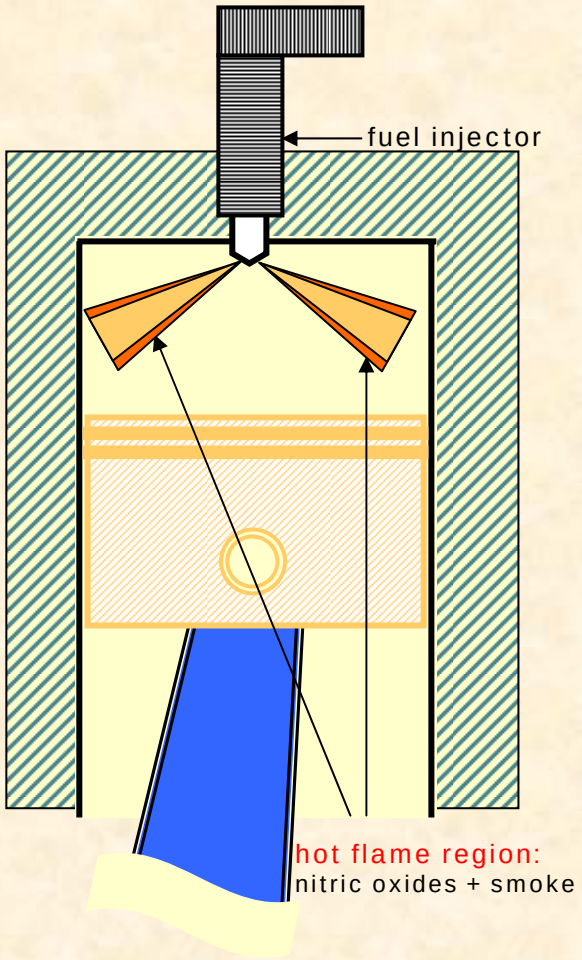
# Advanced Combustion (HCCI, PCCI, HECC, LTC, etc)

- **Fast-moving, rich area of research**
- **Can lower demands on aftertreatment system, maintain/improve efficiency**
- **Difficult to control**

# HCCI distinction from other combustion modes

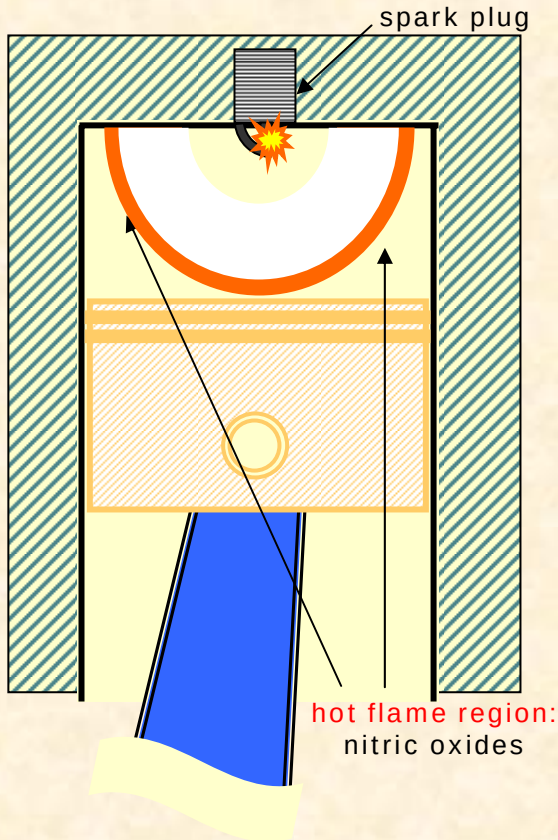
## Diesel Engine

(compression ignition)



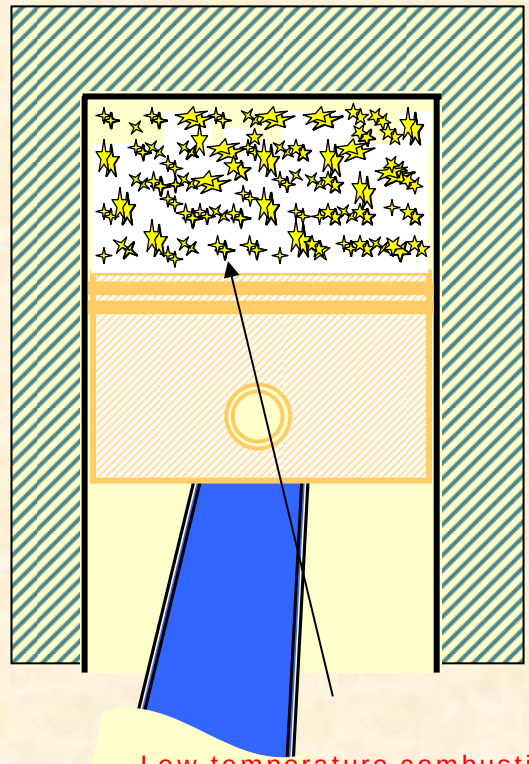

## Gasoline Engine

(spark ignited)




## HCCI Engine

(Homogeneous Charge Compression Ignition)



Low temperature combustion

ultra low emissions !!

Source:Caterpillar, 2003

# LOTS of Challenges to implementing "Novel Combustion" over full operating range

- **Getting fuel in the cylinder and mixed before ignition**
- **Controlling temperature of charge so that ignition occurs at proper time (fuel injection event and start of combustion are relatively far apart**
- **Unburned HC and CO (also, exhaust temp is too low for most oxidation catalysts at light load)**
- **Cylinder-to-cylinder balance**
- **Structural integrity of block (high rates of pressure rise)**
- **Needs small injector holes, manufacturing and plugging issues**
- **Transient operation**

# Contact Information for FEERC

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- **URL for the Fuels, Engines, and Emissions Research Center: http://feerc.ornl.gov**