Advanced Heat Engines Activities

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U.S. Department of Energy
Office of Fossil Energy

Today's Presentation

- Federal Energy Technology Center
- Historical Perspective on Engine Research
- Coal Water Slurry Diesel Program
- Liquid Fuels Engine Research
- Advanced Reciprocating Engine Systems related activities
- FETC activities with the ARES Consortium
- Future Outlook for Reciprocating Engines

What FETC Is

- An industry-focused Federal organization managing and conducting technology development programs
- Government Owned and Government Operated
- FY99 Budget of $717 Million

- More than 600 research activities in 49 states and 16 countries
  - Private Industry
  - Universities/Colleges
  - Not-for-profit laboratories
  - DOE National Laboratories
  - Other Government Laboratories

- Homesites in Morgantown, WV and Pittsburgh, PA
  - 68 Buildings
  - 818,000 Square Feet
  - 24 Major On-Site Research Facilities

- 539 Federal Employees
  - Technical Management
  - In-House R&D
  - Administration
  - E&E Technical & Business Services

- 608 Support Contractors
  - 480 On-Site
  - 128 Off-Site

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FETC Mission

We Solve National Energy
and Environmental Problems

What FETC Does

- **Track energy/environmental trends**
- **Identify advanced technology options**
  - Review technical, cost, and environmental performance
  - Evaluate potential markets
  - Define potential national benefits
  - Identify R&D needs
- **Plan RD&D program**
- **Implement, manage, and conduct RD&D projects**

What FETC Does

- **Interact with industry to:**
  - Understand technology developer's interest
  - Obtain cost sharing
  - Understand user needs
  - Share technical expertise
- **Interact with regulatory community**
- **Provide meaningful input into environmental regulations**
- **Technology transfer**

FETC Business Lines

Cross-cutting Advanced Reciprocating Engines

Clean Affordable Power Systems

- Near-Term Coal Environmental
- Advanced Coal
- Advanced Natural Gas

Clean Affordable Fuels

- Natural Gas Supply
- Coal Liquefaction
- Gas to Liquids
- Solid Fuels & Feedstocks

Industrial Technology

- EE Industries of the Future
- Mining Initiative

Global Climate Change

- Policy Support
- International

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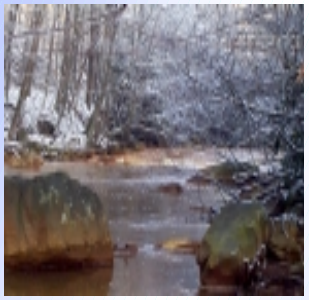
FETC Business Lines

Cross-cutting Advanced Reciprocating Engines

Environmental Management

- D&D Focus Area
- Industry Program
- Large Scale Demo's



Watershed Science and Technology Initiative

- Regional Data Collection
- Watershed Modeling

E&E Technical & Business Services

- CABE
- CHRIS
- Independent Assessments
- Energy Management of Buildings

Critical Infrastructure Protection

- Partnership to support electric, oil, and gas industries

Representative On-Site R&D Facilities

Laboratory Operations

- Computational and Simulation Facilities
- Particulate Flow Analysis Facility
- Science and Analytical Instrumentation Laboratories

Pilot Plants

- Flue Gas Cleanup Facilities
- High-Pressure Fluidized-Bed Coal Gasifier
- Solids Handling Process Research Facility

Bench Scale Facilities

- Combustion and Environmental Research Facilities
- Hot Gas Cleanup Process Development Unit
- Modular Gas Cleanup Reactor Facility

Off-Site R&D Facilities

Power Systems Development Facility at Wilsonville, AL

The nation's first large-scale, modular test center for 21st century power technologies.

Clean Environmental Development Facility at Alliance, OH

The 100 million Btu/hr (10MWe) facility offers a cost-effective way to obtain engineering and performance data on a full suite of conventional and advanced emissions control technologies.

Alternative Fuels Development Unit at LaPorte, TX

This state-of-the-art facility for syngas conversion is the cornerstone of DOE's indirect liquefaction program.

Power System Program Drivers

- **Utility deregulation**
  - Increasing price/supply competition
  - Shift to deregulated business investments
  - Expanding role of ESCOs
- **Distributed generation**
  - Advances in high efficiency “modular systems”
  - Tailored, site specific power solutions
- **Natural gas**
  - Natural gas and oil plentiful and affordable now
  - Coal remains a player in industrialized and developing countries
- **Environment**
  - Increasing international pressures for carbon management policy
  - Downward ratcheting of priority pollutants

Portfolio of Power Systems

Coal Central Station

IGCC - Greatest Flexibility
PFBC - Opportunity Fuels
LEBS - Build on Existing Infrastructure
HIPPS - Retrofit Opportunities
Vision21 - Culmination of Program

Gas Central Station

ATS - Leapfrog in Performance

Gas Distributed Power

MCFC - High Efficiency
SOFC - Low Cost
Hybrid Turbine/Fuel Cell - Ultimate Efficiency
PAFC - Entering Commercial Market
RECIP Engine - Lowest Cost

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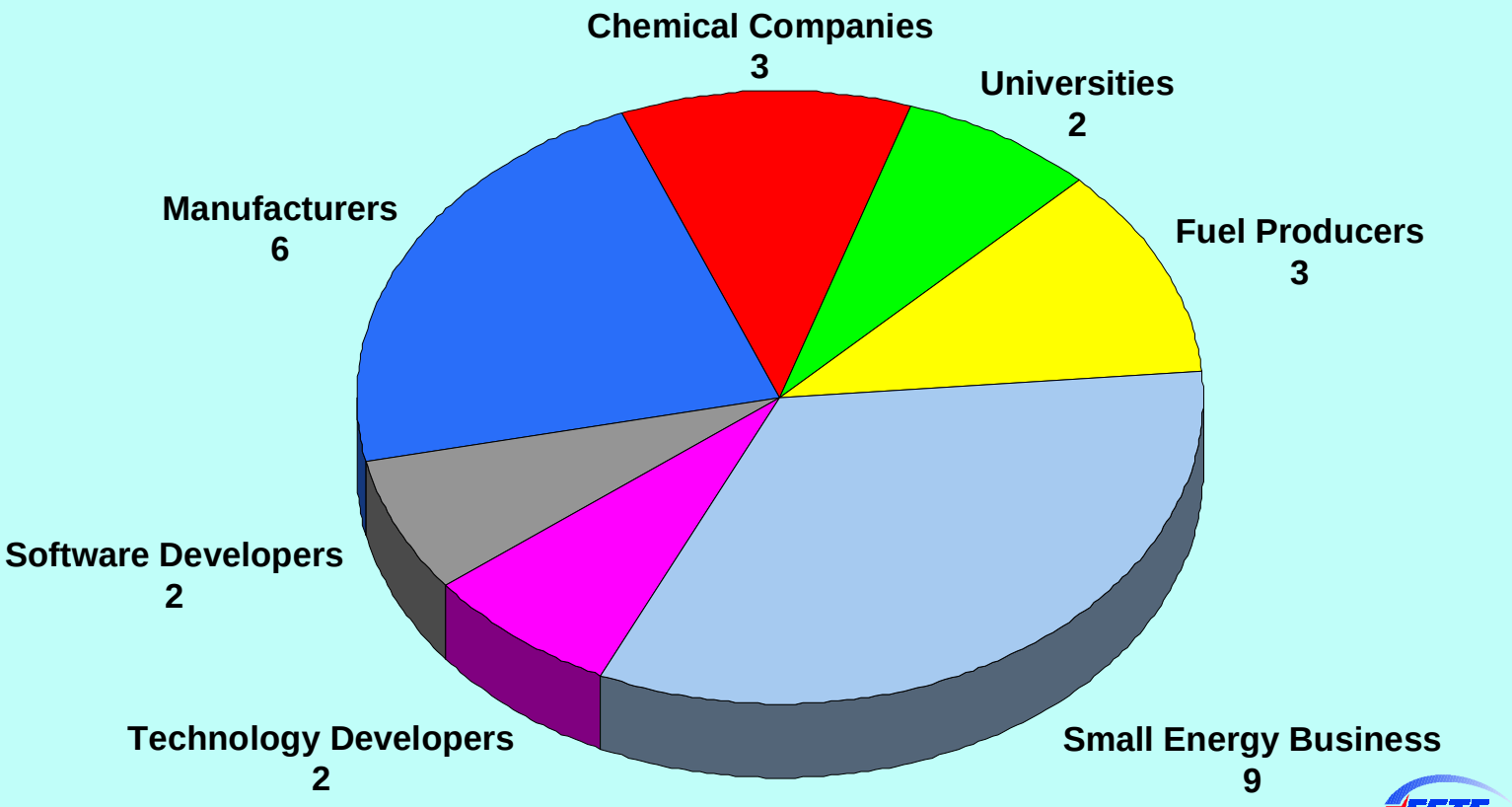
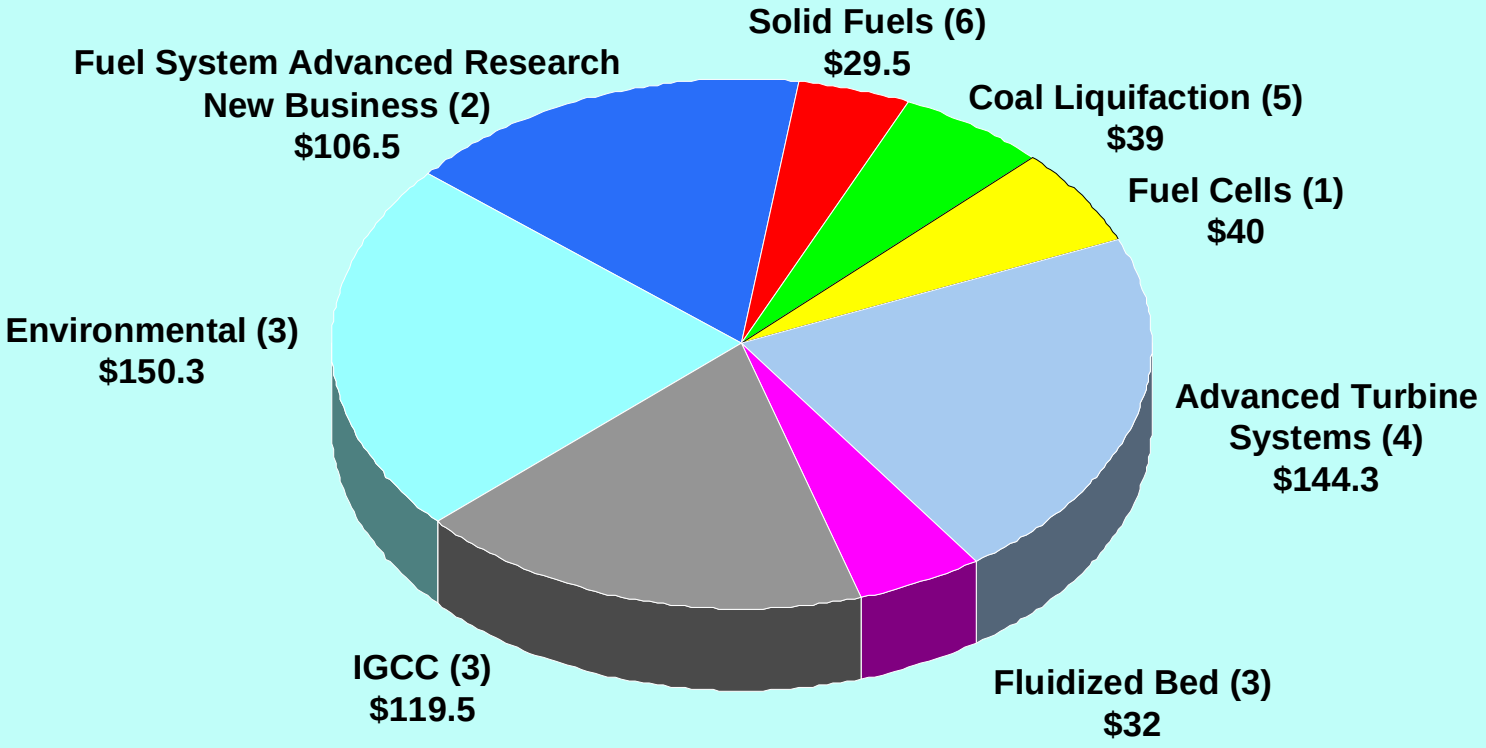
Who are FETC's CRADA Partners

(FY 98 - 27 Active)



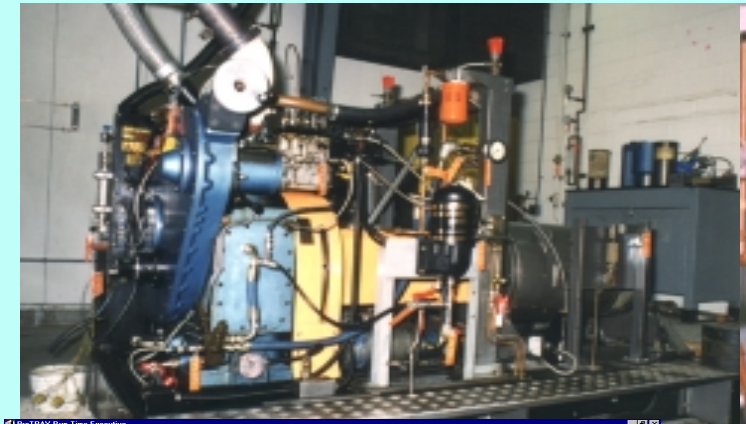
Product Area Emphasis of FETC's CRADAs

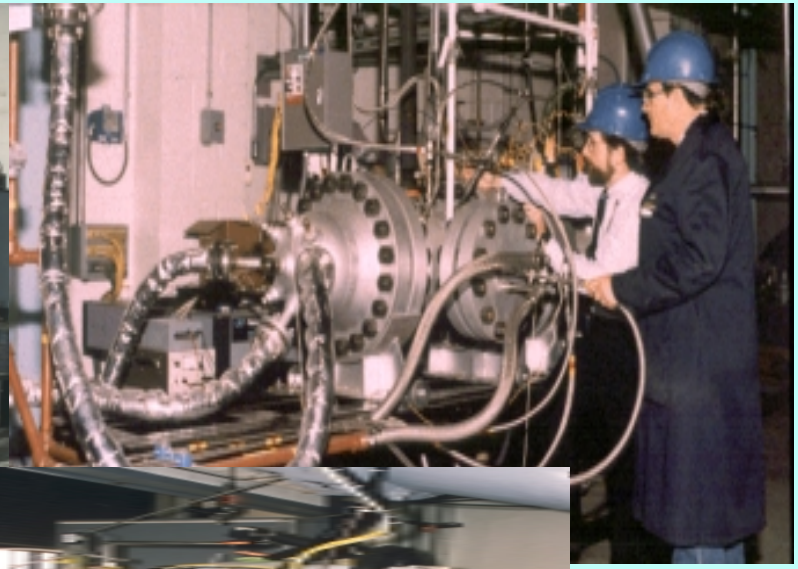
(OST Only - K Dollars - FY 98)

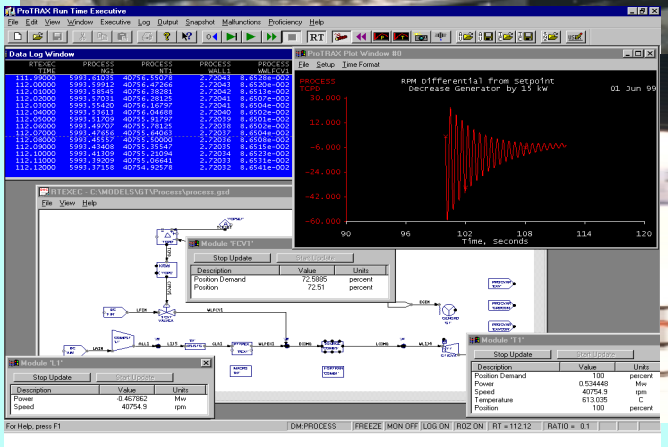


$661K - Value (FETC share) of the 27 CRADAs

FETC Expertise in Engine Combustion and Fuels Technology







FETC's Advanced Heat Engines Product Team

- Abbie W. Layne - Product Manager, MS Mechancial and Aerospace Engineering
- Patricia Rawls- Evaluation and Planning, MS Industrial Engineering
- Patrick Le - Process Engineering, MS Mechancial Engineering
- Mike McMillan - Office of Science Technology, P.E. PhD candidate in Mechnical Engineering
- George Richards - Office of Science Technology, Ph D Mechanical Engineering
- Chuck Alsup - Gas Power Systems Division, BSME/MSIE
- Norman Holcombe - Gas Power Systems Division, PhD Chemistry
- Richard Johnson - Gas Power Systems Division, Ph D Chemistry
- Kanwal Mahajan - Gas Power Systems Division, MS Chemical Engineering

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Combustion Division

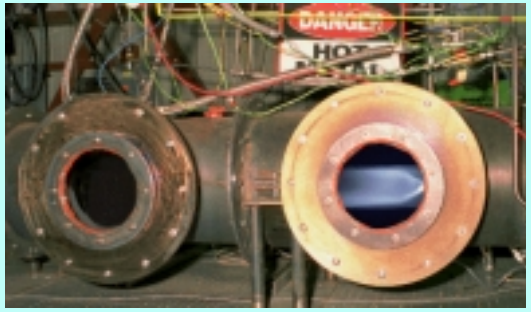
Low Emissions Combustion Test Rig -

- Porous radiant burner
- Humidified cycle combustion
- Dynamic Gas Turbine Combustor
- Tested "active" and "passive" control techniques
- Emerging work aimed at reducing turbine fuel sensitivity, fuel premixing problems and flashback.

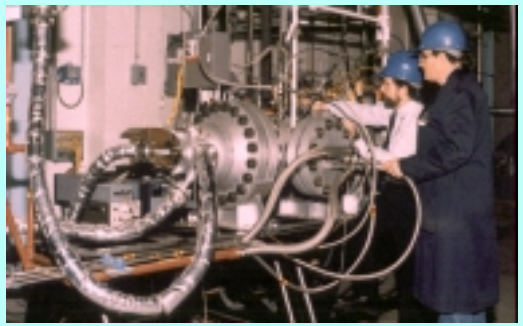
Atmospheric Pressure Test Rig

- Currently modifying for fuel flexibility studies

Low Emission Combustion Test Rig



Atmospheric Pressure Test Rig



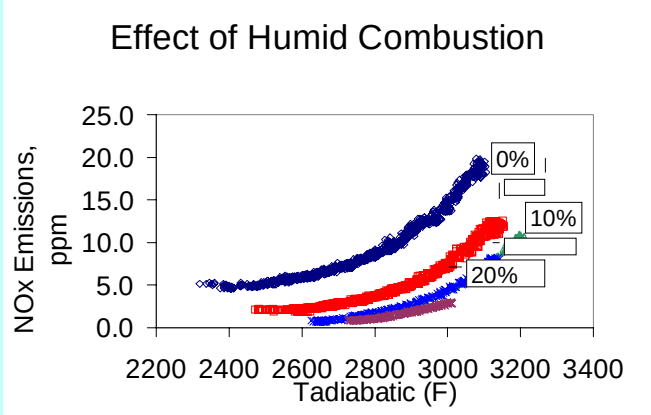
Dynamic Gas Turbine Combustor

U.S. Department of Energy - ORNL & FETC

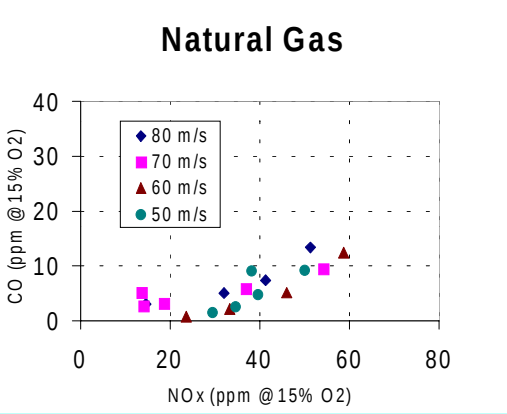
M98000261C

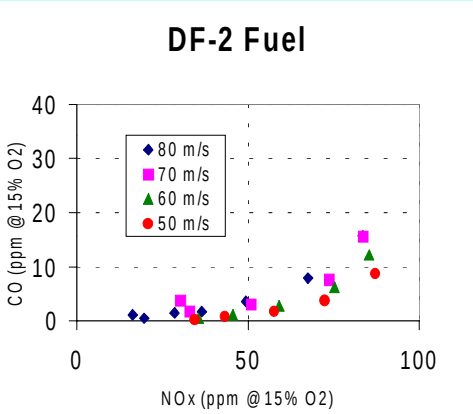
Low-emission combustion

Tests of HAT-cycle combustion and dual-fuel offer added capability to ATS engines and ATEP concepts.



Dual-fuel premixer

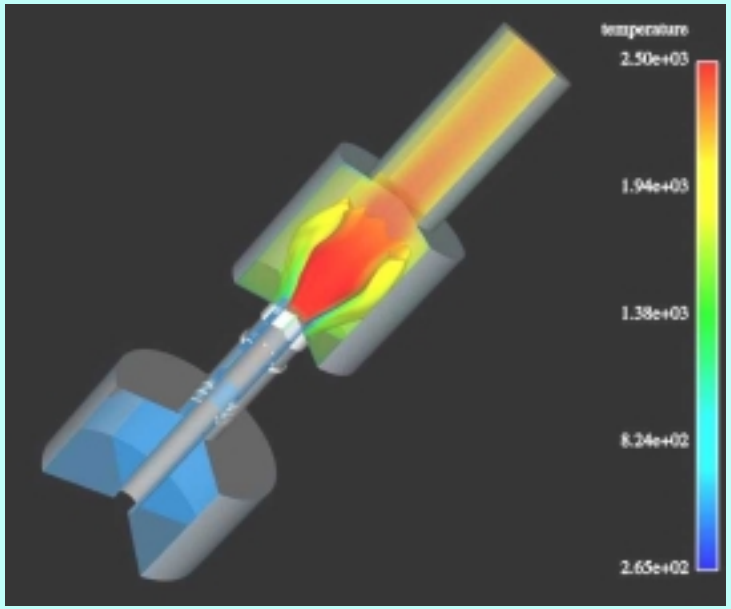




FETC is using advanced simulations to remove the barriers to low-emission combustion.

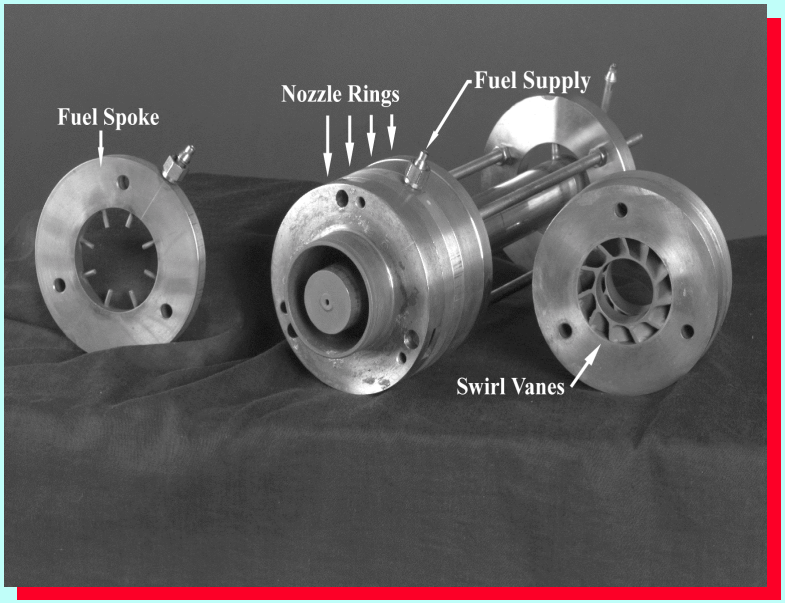
Detailed simulation of FETC lab results appears to explain role of key injector design features affecting combustion dyanmics.

Pittsburgh Supercomputer Results



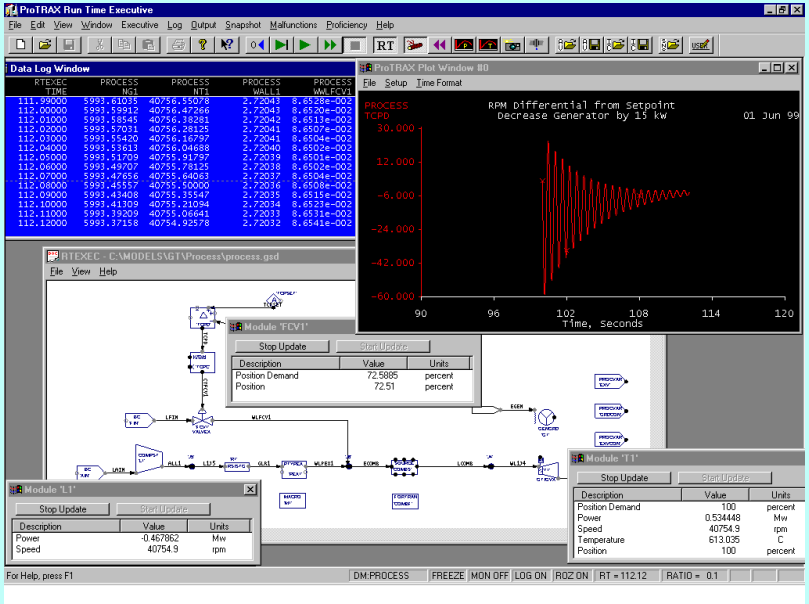
Temperature field produced by the FETC injector

FETC Research Fuel Injector

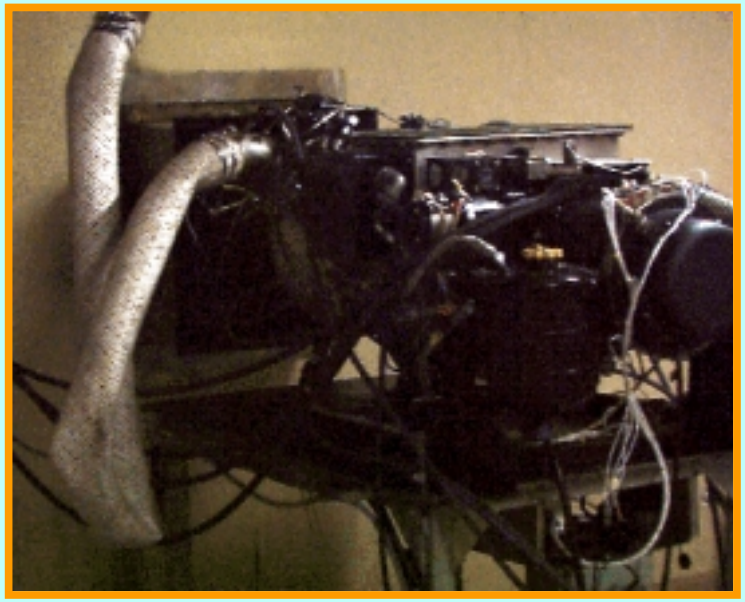


Emerging hybrid cycle activities

Dynamic simulation of hybrid engines

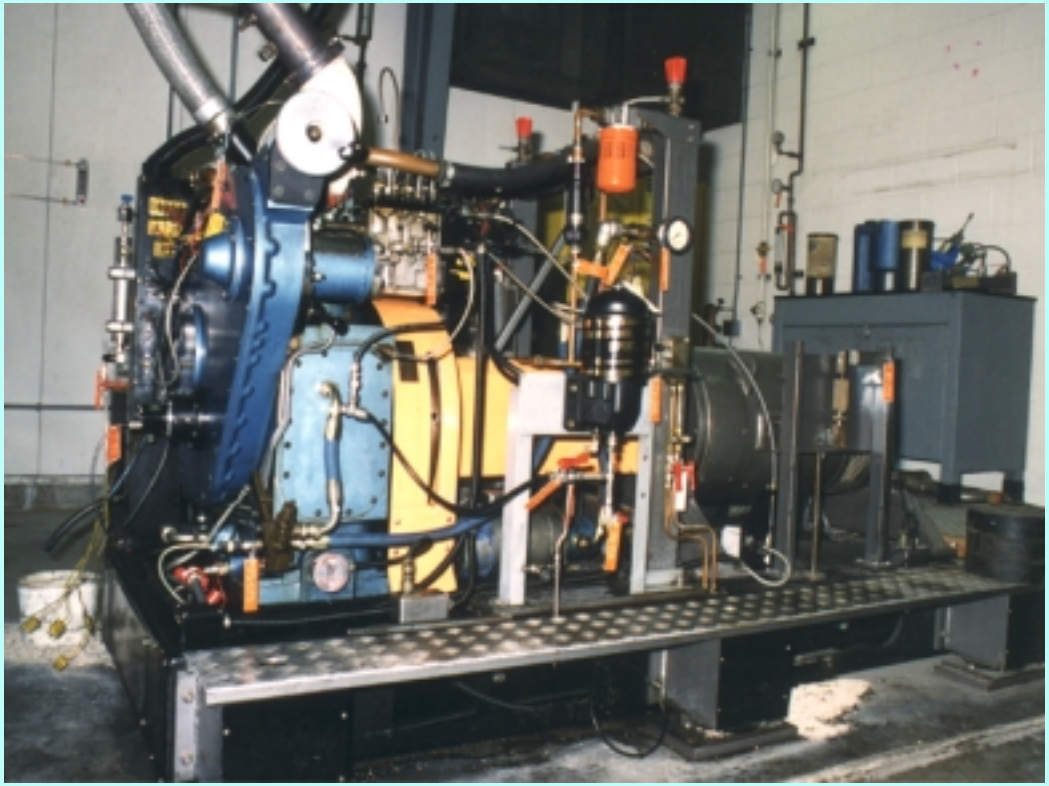


Turbine engine planned for hybrid studies



FETC Engine Laboratory

FETC Engine Lab Single Cylinder Research Engine



FETC Engine Lab Mini Dilution Tunnel

FETC Engine Lab Gas Emissions Cabinet

FETC F-T Engine Performance and Health Effects Studies

- **Objectives**
  - Compare engine emissions of PM, NOx, CO and THC on FETC single cylinder research engine for:
    - Standard 0.05% S diesel fuel
    - F-T Blending Fuel from Shell Bintulu Fixed Bed Reactor
  - Combustion analysis of both fuels
    - Compare peak pressure, heat release rate, burn durations, key parameter location, etc.
  - Compare health effects of engine particulate emissions for each fuel as function of particle size
    - Genotoxicity, Mutagenicity via invitro bioassay analysis

FETC Knock Mitigation via Laser Ignition

- ***FETC In-House Supporting the ARES Consortium***

  - **Develop a novel rapid compression constant volume combustion apparatus (RCCVCA) for natural gas engine combustion simulation.**
  - **Conduct fundamental studies of laser ignition at ARES gas engine conditions (Tran, P.X., "Multi-Point Laser Ignition of Gaseous Fuels," *Combustion Science and Technology, (In Review),* 2000.**
  - **Learn to establish knocking conditions in the RCCVCA, thus allowing an in depth understanding of the knocking mechanism**
  - **Use the developed understanding of the knocking mechanism and laser ignition to control knock while simultaneously providing reliable ignition source.**
  - **Work with SWRI and engine consortium to develop viable ignition system and knock control strategy**

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External Projects Supporting Reciprocating Engines

Summary of FETC Coal-Fueled Diesel Program

- **Initial efforts began in 1982**
  - FETC in-house engine facilities established in 1986
- **Large-scale SEB development CWS-fueled diesel engine program began in early 1985**
  - Program was a technical success
    - Diesel locomotive operation at GE
    - Stationary medium-speed engine developed at Cooper-Bessemer, over 2,000 hours operation
    - Successful operation by SWRI and DDC with 1900 rpm DDC 8V-149 high-speed engine
- **Demonstration project at University of Alaska Fairbanks**
  - Coltec
  - Shakedown (engine operation) began 9/13/99 using Alaska low-rank coal

Coltec 18-cylinder Coal-Fueled Diesel being unloaded at UAF

Installed Coltec Engine

Advanced Reciprocating Engine Consortium

- FETC currently implementing ARES Consortium for Office of Fossil Energy and Office of Industrial Technologies
- South West Research Institute(SWRI) established/current over-site of consortium for DOE-FETC
- DOE consortium funding from FETC-FE and EE-OIT
- Consortium winds down in Dec of 2000
- Assists in defining technology pathways for ARES program

Advanced Turbines and Engines Program (ATEP) - Federal Energy Technology Center

- **Next Generation Gas Turbines**
  - **Vision 21**
  - **Flexible Gas Turbine Systems**
  - **Supporting Research & Development**
- **Advanced Engine Systems**
  - **Supporting Research & Development**
  - **Advanced Reciprocating Engine Systems**
  - **Novel Concepts**

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Future Outlook for Reciprocating Engines

- FETC and Office of Fossil Energy(FE) are committed to supporting R&D for advanced reciprocating engine systems
- Advanced Turbines and Engines Program
- FETC-FE will contribute to consortium and follow-on program in FY 2000-2001
- FETC-FE long term commitment and plan for reciprocating engines programs thru FY 2010

Reciprocating Engines:

- **Ultra Clean Generation**
- **Unsurpassed Efficiency**
- **Distributed Generation**

***Power* for the next millenium**