Usage Issues and Fischer-Tropsch Commercialization

Presentation at the CCTR Advisory Panel Meeting

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Diesel Engine Research

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Gas Turbine Research

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F-T Diesel Fuels Research

Diesel engine designers are faced with challenge of reducing particulate and NO_x emissions. Need for after-treatment devices and high levels of exhaust gas recirculation in current engines. Results in increased cost.

Process modification can change Fischer-Tropsch fuels (F-T fuels) to meet specific requirements, e.g. cetane number, lubricity, volatility.

Fuel structure modification will enable the combustion process to be altered to meet the limits on pollutants at lower cost.

F-T Diesel Fuels Research (continued)

Economic cost of modifying F-T fuel has to be weighed against economic benefits. Engine tests and after-treatment catalyst evaluation will determine economic benefits.

Integrated program focusing on fuel modification and engine and after-treatment designs will maximize benefits of utilizing F-T fuels.

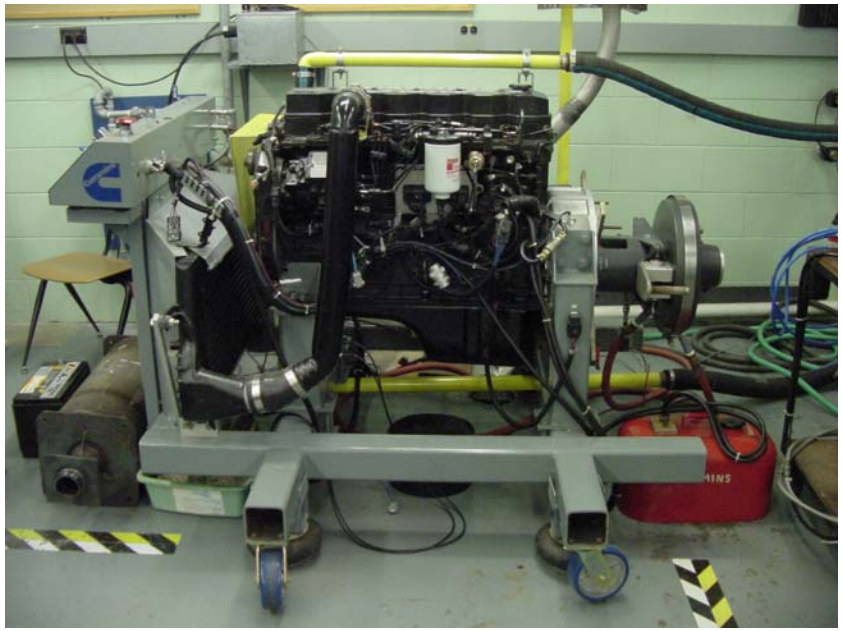
Existing engine test facilities have to be upgraded to carry out integrated fuels and engine research, provide the level of detail required to maximize the benefits from both components, and provide realistic economic assessment.

Diesel Engine Test Facility

- October 2002 Certified ISB 5.9 L Cummins Diesel – EGR & VGT (with Cummins Calterm II 7.63)
- 800 hp Eddy Current Dynamometer w/ Dyn-Loc IV Controller

Diesel Engine Test Facility

- 1998 ISB 5.9 L Cummins Diesel
- 500 hp Go-Power DT-1000 Water Brake Dynamometer



Diesel Engine Test Facility

Additional facilities include:

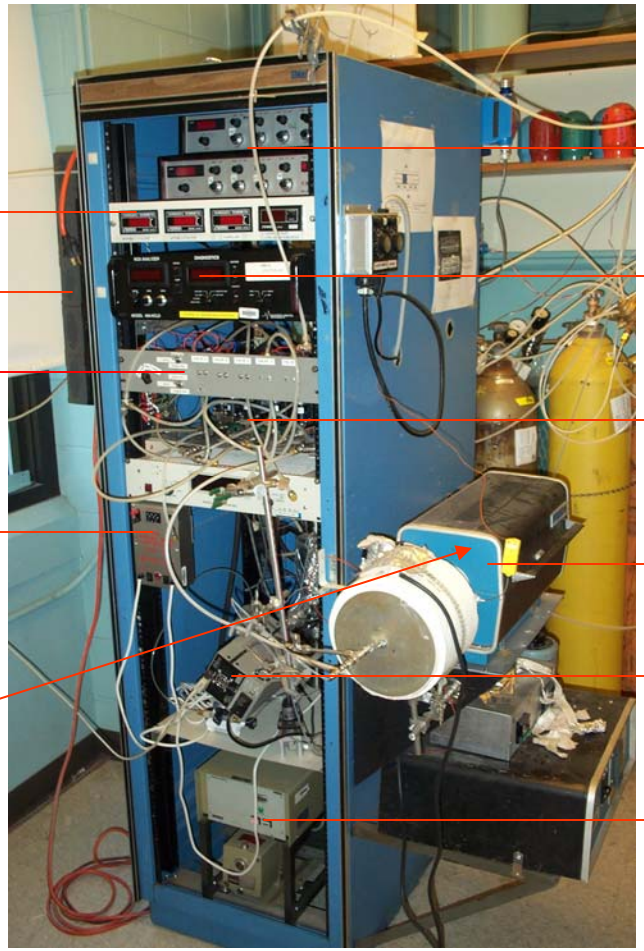
- Cummins B-series engine with in-cylinder pressure transducer, and optical shaft-encoder, on an eddy-current dynamometer/controller.
- Single-cylinder version of the Cummins N-series engine with in-cylinder pressure transducer, optical shaft-encoder, external regulation of oil and coolant temperatures, external regulation of intake air pressure and temperature, capability to measure fuel and air flow rates, on an electric dynamometer/controller. This engine has been used for evaluation of piston bowl shapes, swirl numbers, injectors, and alternative fuels.
- Computerized data-acquisition/analysis systems for measurements and analysis of in-cylinder pressure, heat release rates, and exhaust gases.

Emissions Measurement Capabilities

Combustion Emissions Analyzers:

- **HC**: HFR 500 Fast FID (Flame Ionization Detector)
  (0.9 ms Response Time)
- **NO** & **NO_2**: fNOx 400 Fast CLD (Chemiluminescent Detector)
  (<2 ms Response Time)
- **PM**: AVL Smokemeter
- **CO** & **CO_2**: NDIR (Non-Dispersive Infra-Red Detector) 500 Fast CO & CO_2
  (5 ms Response Time)

Reaction Unit for Kinetic Measurements of After-Treatment Systems



Temperature Display

Data Collection Module

Automatic Valves

Water Feeding Pump

MFC Controllers

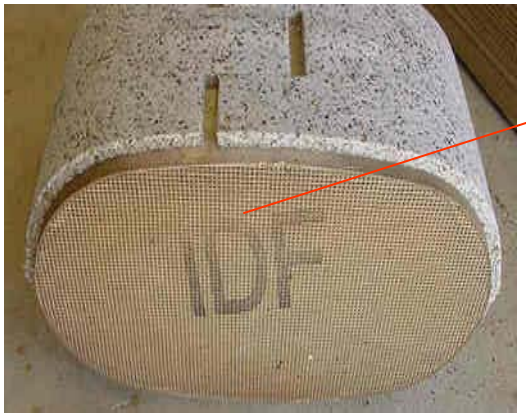
NOx Analyzer

Mass Flow Meters

Reactor Oven

Mass Spectrometer

Turbo Pump



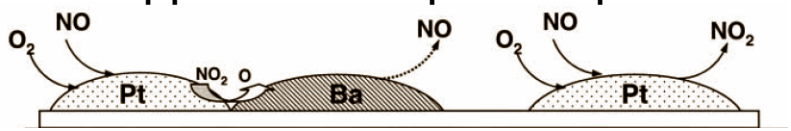
Catalyst

After-treatment Model Development

Important Assumptions

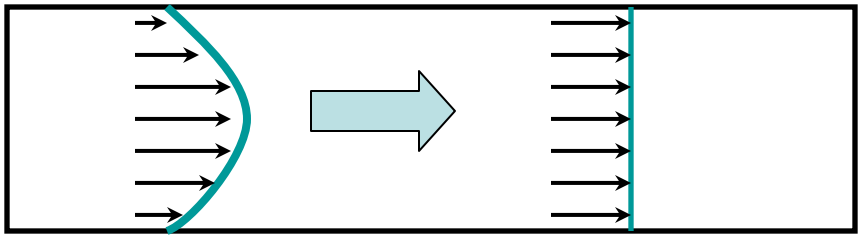
Complex porous catalyst washcoat

Flat support with deposited particles

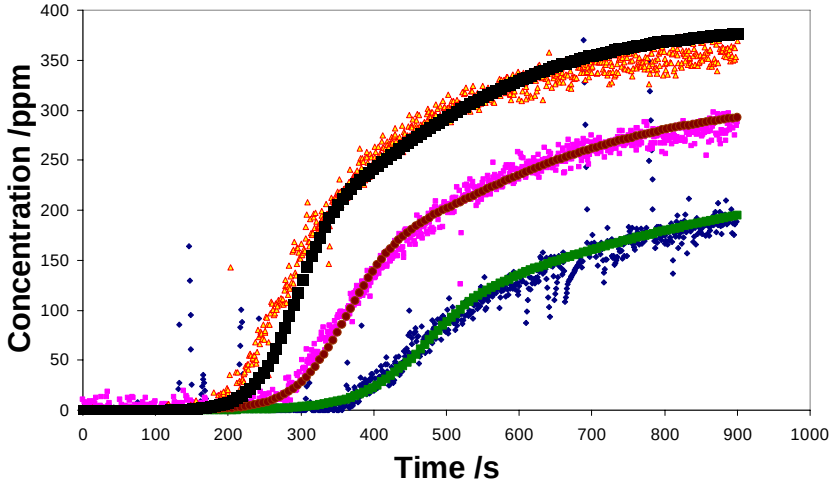


Flat uniform surface

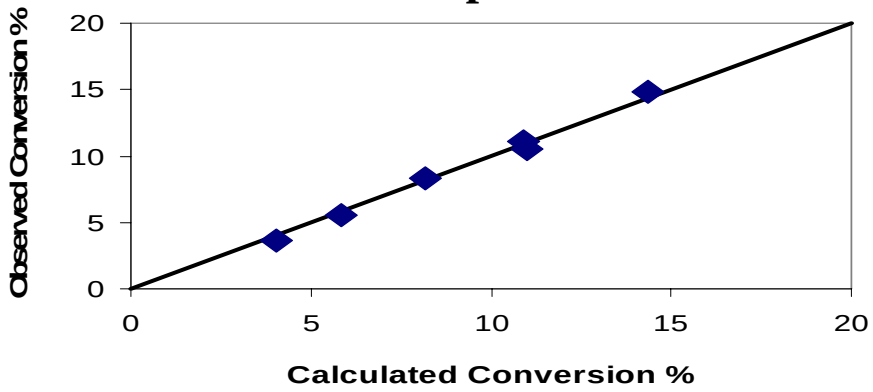
Laminar Flow Plug Flow



NOx breakthrough curves



Oxidation predictions



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F-T Fuels in Diesel Engines

Proposed Work

- Evaluate F-T fuels and fuel blends of known properties; engine performance parameters, including emissions, will be measured.

- Extend NO_x after-treatment model for $NO/NO_2/CO/CO_2/H_2O$ inlet compositions that are relevant for diesel engine running on F-T fuels.

F-T Fuels Utilization in Gas Turbines

Aircraft Gas Turbines

Use of F-T fuel as an endothermic coolant for aircraft systems – endotherms and coking behavior must be investigated

Particulate generation – investigation of sooting behavior of F-T fuels and blends with JP8 – low aromatic content may lead to lower soot emissions

In general, atomization, mixing, ignition properties of F-T fuels and fuel blend must be studied systematically

F-T Fuels Utilization in Gas Turbines (continued)

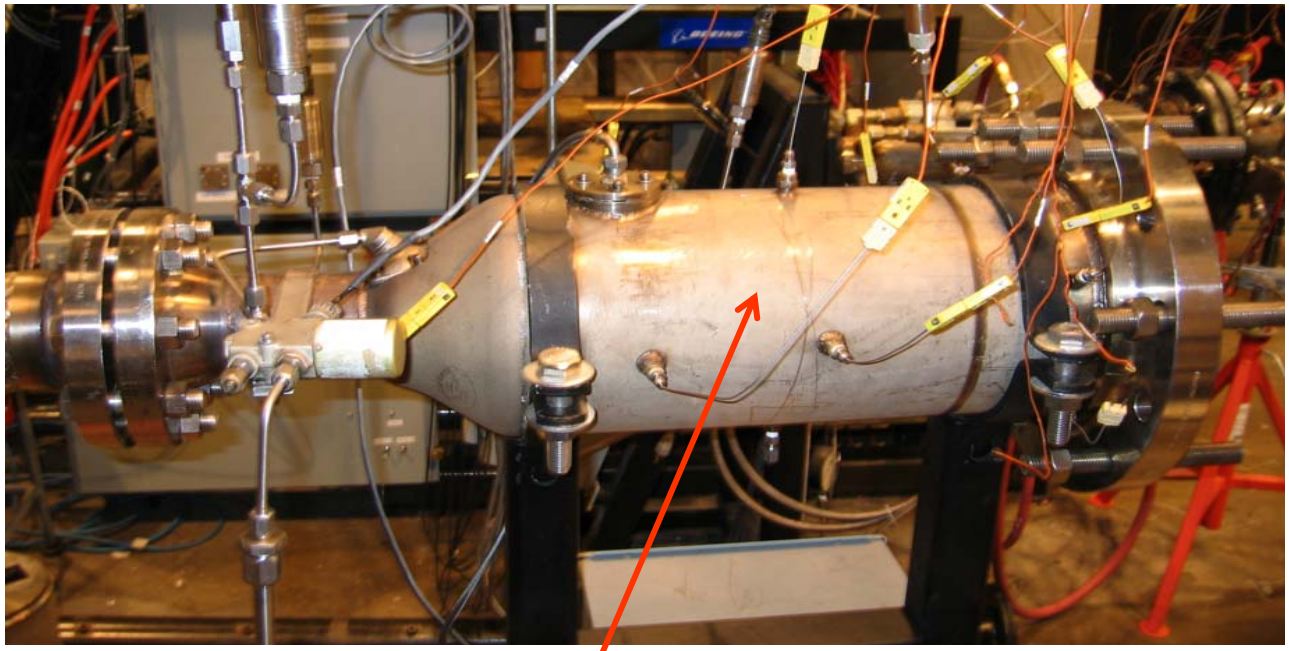
F-T Fuels in Power-Generating Gas Turbines

Modern power-generating GT systems operate very fuel lean to reduce pollutant emissions – combustion stability of F-T fuels and fuel blends, pollutant formation at high pressure are areas of great interest

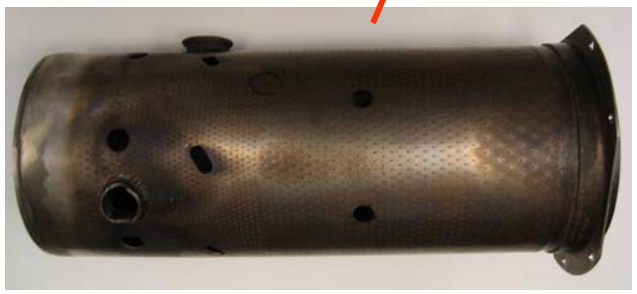
Active control methods to reduce combustion instability must be developed

Atomization, pre-mixing, fuel distributions in premixer/ignitor devices must be studied

F-T Fuels Utilization in Gas Turbines



GT Combustor Facility in the High Pressure Laboratory

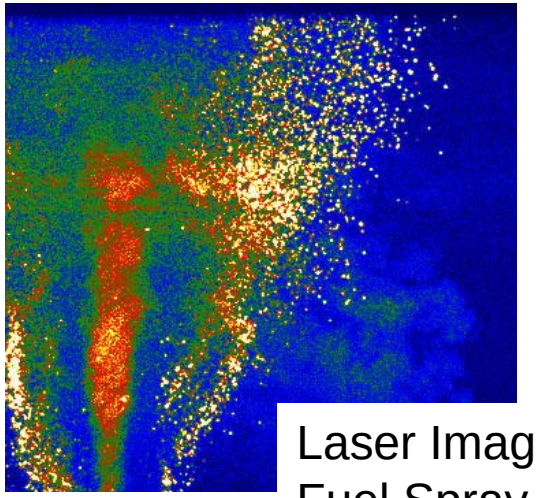


Rolls Royce Combustor Can

Zucrow Lab Facilities for Gas Turbine Testing

HP Air Tanks

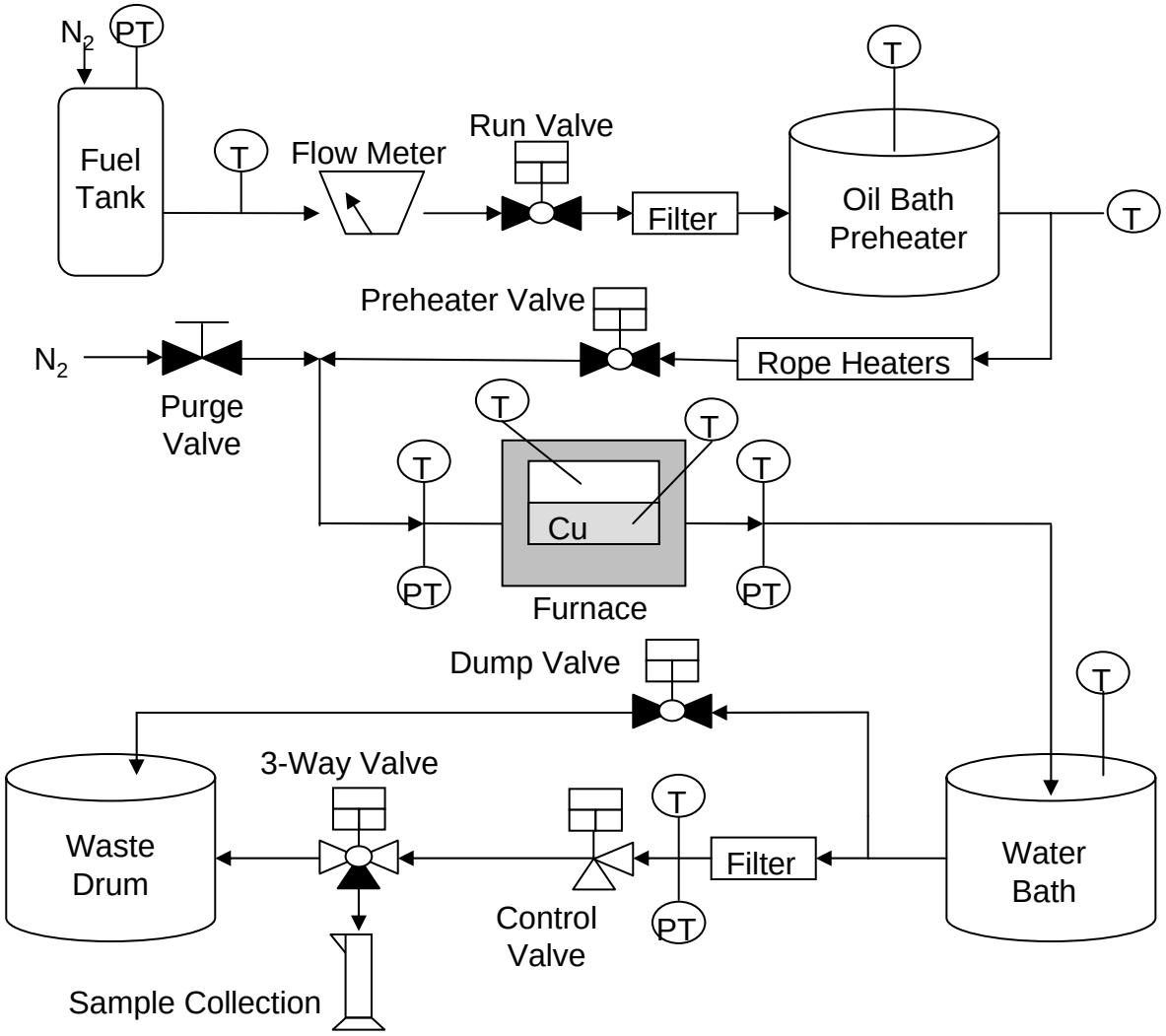
- 2000 actual cubic feet of 2,000 psi air storage
- Recently modernized air compressor plant produces nearly 1 lbm/sec of dry air at 2,000 psi
- Large natural gas fired heat exchanger capable of 950 deg F air discharge temperature at 9 lbm/sec and 700 psi
- Precise flow rate and pressure control with large dome-loaded pressure regulator and sonic orifices, system blow-down performance well characterized



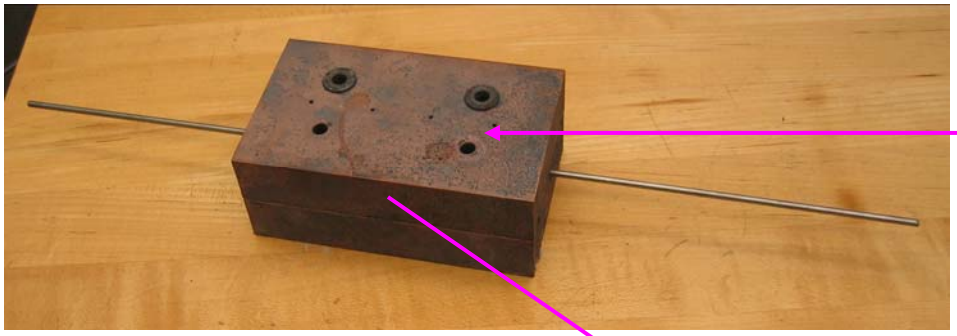
Laser Imaging of Fuel Spray

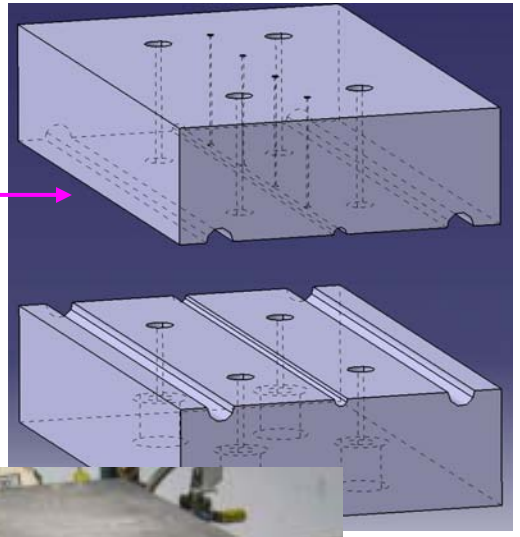
- Recently upgraded emissions monitoring system, state-of-the-art FTIR and flame ionization detector installed
- Laser diagnostic capabilities for probing harsh GT environment are being developed

F-T Fuels Coking Test Facility

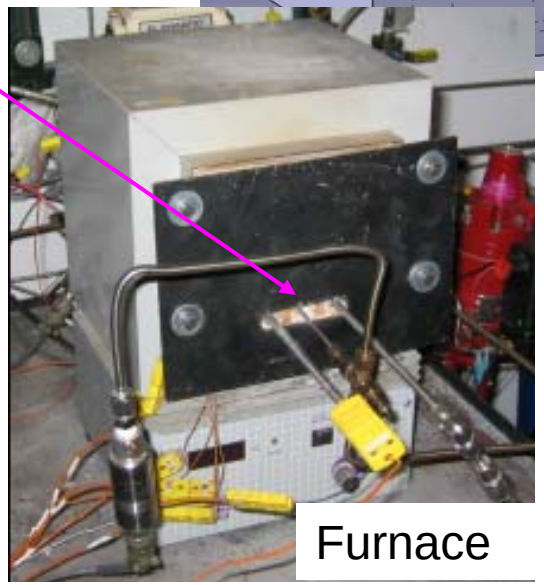


F-T Fuels Coking Test Facility





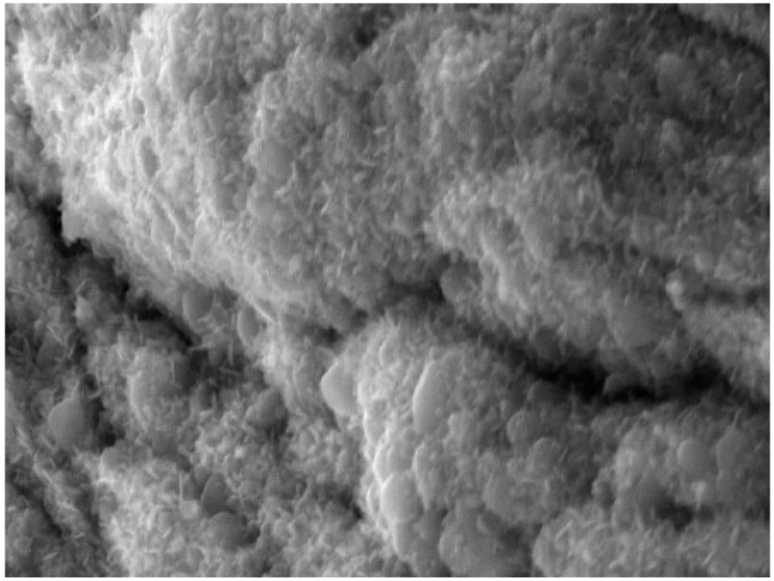
- Test tube consists of a 5" heated length, is 0.125" o.d., 0.067" i.d. (Inconel) or 0.063" i.d. (SS316)
  - Cut into 1” segments; carbon burn-off detects coke
- Tube wall temperatures are measured with spot-welded thermocouples

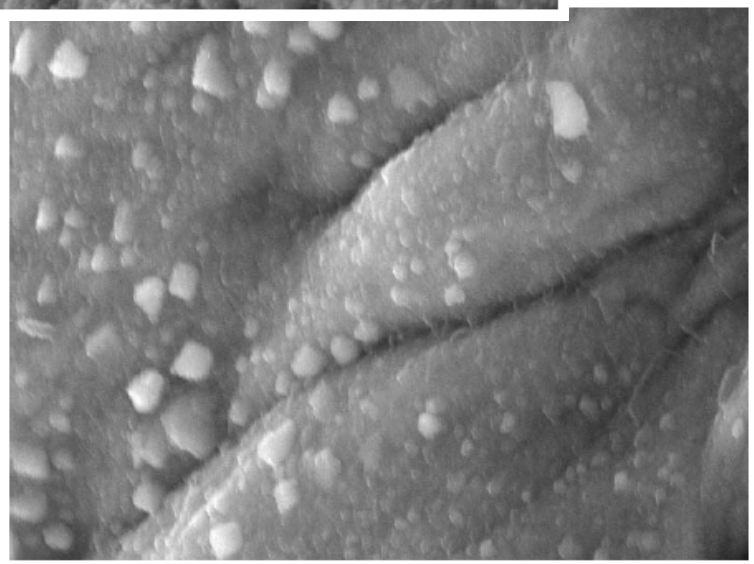


Furnace

Fuel Effects on Coking

JP-8





JP-10

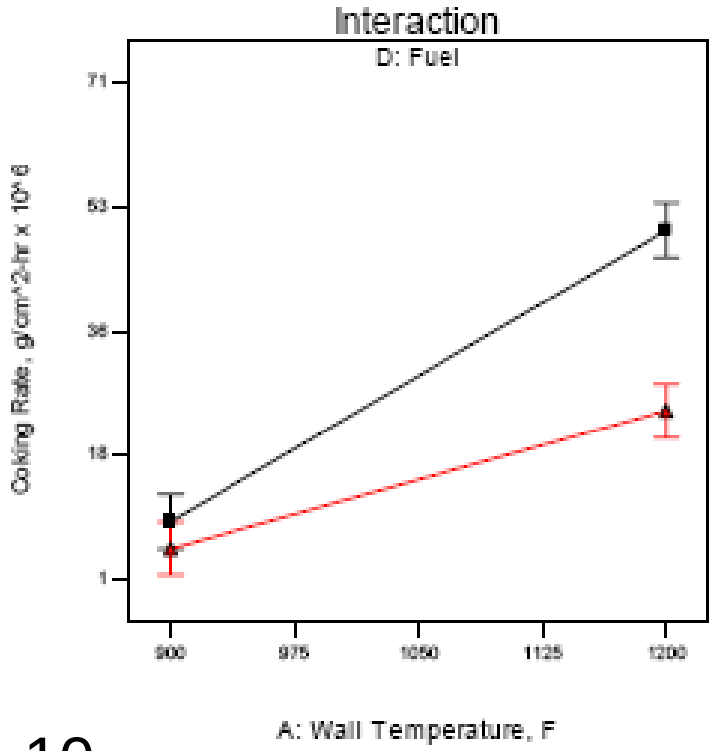
Design-Expert® Software

Coking Rate

■ D1 JP-8
▲ D2 JP-10

X1 = A: Wall Temperature
X2 = D: Fuel

Actual Factors
B: Flow Rate = 0.936
C: Material = SS316



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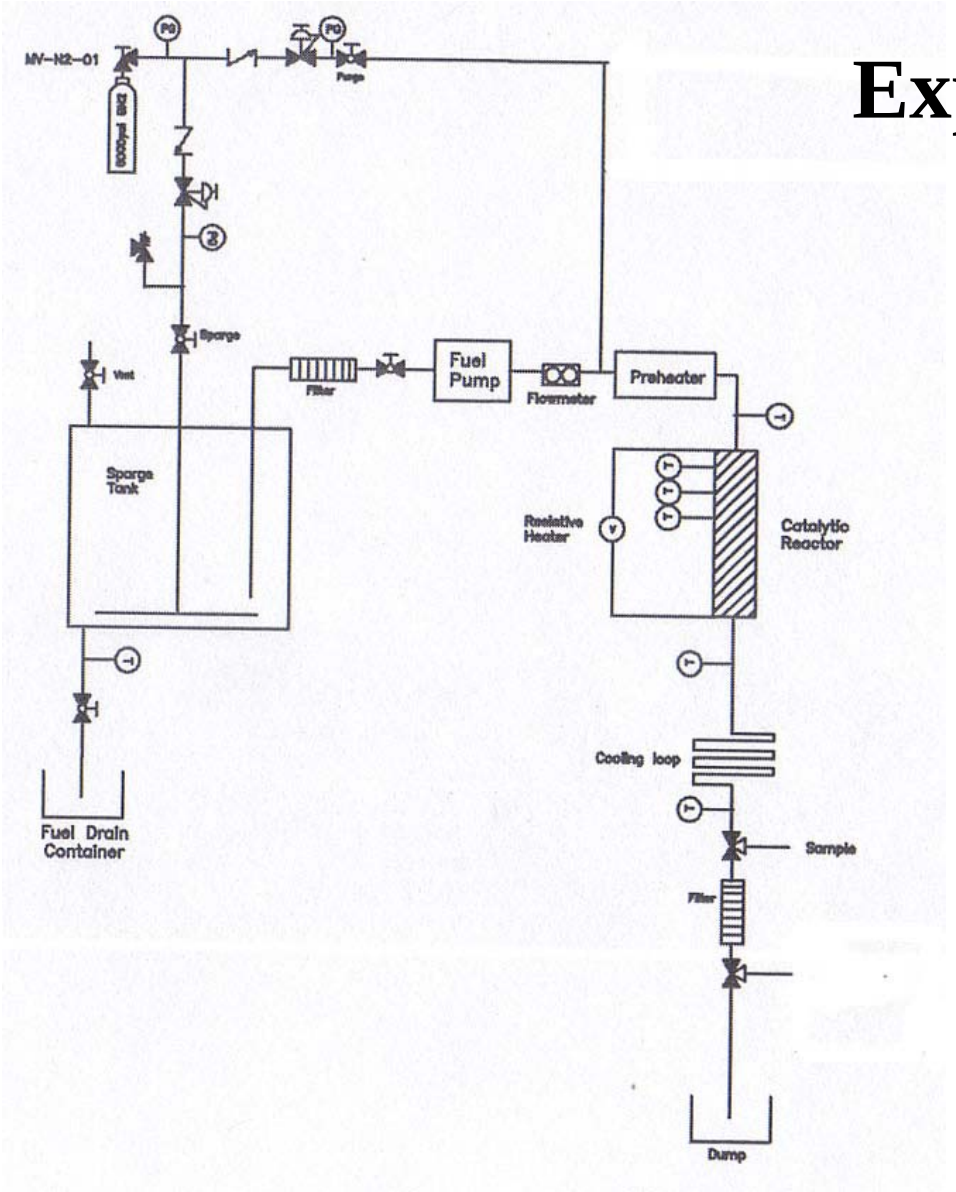

Endothermic Fuel Experimental Apparatus

- Endotherm measurement
- Product species
- Coking rate
- Resistively heated reactor for simple endotherm calculation

F-T Fuels in Gas Turbine Engines

Proposed Work

- Initiate studies on specifications of fuel for aircraft gas turbine engine use.
- Identify desirable chemical structures for non-coking endothermic fuels.
- Test coking properties of FT fuels and fuel blends.
- Test ignition, performance, and emissions for FT fuels and fuel blends in Zucrow Laboratories gas turbine combustion facility.