ALTERNATIVE FUELS

GAS FUEL INTERCHANGE

OVERVIEW

Rising utilization and tight supplies of natural gas are leading to higher fuel prices for California. These high prices are motivating end-users to explore the feasibility of burning alternative or "opportunity" fuels in an effort to rein in fuel costs. Use of unprocessed natural gas, coal bed methane, landfill and digester gases, biomass and coal-derived gases (e.g., synthetic natural gas), and hydrogen is expected to increase if these fuels are readily available and economical. As the spectrum of fuels available in California widens, it will be important to understand the impact that fuels of different compositions will have on the existing base of combustion equipment within the state. Existing interchangeability indices tend to focus on fuel throughput and do not explicitly consider combustion characteristics that might otherwise impact operability and/or emissions characteristics of systems operated on a range of fuel types. Benefits of increased fuel flexibility will be offset if these fuels result in reduced combustion system efficiency, increased maintenance costs, or degraded air quality.

Interchangeability has been defined as "the ability to substitute one gaseous fuel for another in a combustion application without materially decreasing operational reliability, efficiency or performance while maintaining air pollutant emissions within regulatory limits." According to this definition, within the context of advanced lean combustion approaches, ignition conditions, ignition times, burning velocities, heat release and extinction conditions, as well as Rayleigh-criterion oscillation-amplification responses and pollutant emission levels, are all relevant to interchangeability. Current practice, however, does not address all these characteristics. Instead, widespread use is made of the Wobbe index, W, defined as the heating value of the fuel divided by the square root of its density, as a measure of interchangeability. In 2004, the California Public Utilities Commission set the allowable Wobbe Index range to be from 1279 to 1385. SoCalGas argued that 1385 was too low; the South Coast Air Quality Management District argued it was too high. This index, however, has no direct implication of combustion quantities that depend on chemical kinetics, such as ignition times, burning velocities and pollutant formation and emission rates. Its definition is motivated only by considerations of thermal output at constant geometry and injector-orifice pressure drop. While such an index plays an important role from a fuel delivery view point, it is not sufficient for addressing interchangeability from the point of view of combustion system behavior.

In the advanced lean premixed systems currently favored by industry toto minimize NOx emissions, fuel variability can accentuate problems of oscillatory combustion, increasing maintenance costs and reducing system service life. Thus, a need for methods of rating fuel mixtures with respect to their safety and performance in gas-turbines and other practical applications is evident. Again, existing indices such as Wobbe index are not able to infer how combustion systems will behave in light of fuel composition changes. Better understanding of combustion characteristics of fuel mixtures is needed for developing improved methods for evaluating interchangeability of gaseous fuel mixtures.

A number of important parameters need to be considered, besides those appearing in the Wobbe index. These include burning velocities (both laminar and turbulent), critical conditions for autoignition, autoignition times, critical conditions for flame extinction and NOx production rates. These additional parameters depend on the chemical kinetics and transport properties of the flames. They need to be determined as functions of fuel composition, including, at a minimum, the methane, ethane, butane and propane content of the fuel. Although current knowledge of chemical kinetics and transport properties enables computations of these quantities to be made for some fuel mixtures in laminar flows, uncertainties exist that require further experimental testing. A major challenge is the extension of results to practical systems which generally feature turbulent flow fields and may operate at conditions for which data, even at laminar conditions, are not available. Experimentally verified predictions can then provide the basis for development of suitable indices.

In 2006, PIER initiated research to investigate the potential safety, performance, emissions, and air quality impacts of increased variability in delivered natural gas in California. That project is looking at the interchangeability of commercial and industrial burners and home appliances and the potential indoor and regional air quality implications of such gases using existing interchangeability indices. PIER initiated a project in 2007 to evaluate the performance of natural gas vehicles using various natural gas blends (based on expected LNG imports to California) and the air pollutant emissions impacts of using those gases. Testing will address issues such as the impact of the different LNG blends on power, knock potential, fuel economy/CO2 and emissions of pollutants.

APPROACH

The approach taken will involve several universities as summarized in Figure 1.

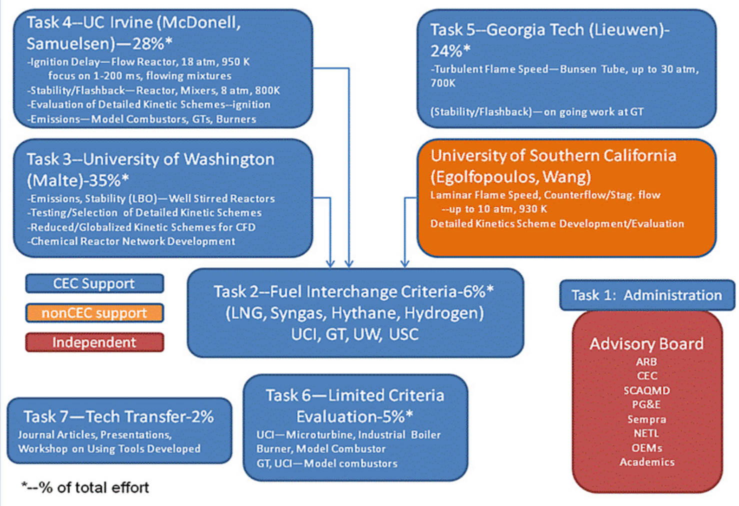

Figure 1. Overall Project Approach

GOALS

The objective of this proposed project is to increase knowledge of combustion characteristics of fuels so that criteria in addition to the Wobbe index can be defined, resulting in improved predictability of combustion behaviors of different fuels and of emission, on the basis of more appropriate gaseous fuel interchangeability criteria (GFIC). This project involves Georgia Tech and the University of Washington. Examples of criteria expressions include correlations/relations for:

- Ignition Delay time [fuel type, composition, conditions]
  - reaction rates, induction time, contaminants, catalysts……
- Flashback Propensity [fuel type, composition, conditions]
  - Turbulent flame speed, diffusivity, quenching, strain, time scales….
- Stability Limits [fuel type, composition, conditions]
  - Time scales, turbulent flame speed, strain….
- Criteria pollutant emissions [fuel type, composition, conditions]
  - Kinetics, mechanisms, reaction rates, time scales….

Ideally these expressions can assembled into a "stand alone" tool or they can be incorporated into CFD models. It is also possible to generate "hybrid" approaches which may involve combining CFD with chemical reactor networks. In all cases, validated expressions for flame speed, chemical kinetic mechanisms, and pollutant kinetics will be needed.

PERSONNEL

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