CERC Clean Energy Research Centre

Laboratory Summaries:

- **High Headroom Lab**

Emission reduction and control lab:

In the catalytic deNOx project, a novel fluidized bed reactor has been developed for the combined adsorption and catalytic reduction of nitrogen oxides in combustion flue gases. A fixed bed reactor is used for catalyst evaluation before the selected catalysts are used in the lab-scale fluidized bed reactor for the performance tests. The successful development of this novel deNOx process will contribute to the advanced control of NO_x emissions from both stationary and mobile combustion sources.

Cleaning of high temperature pressurized gases is a critical step for several promising new technologies under development, including integrated gasification and combustion process for power generation using coal and biomass. A new high temperature and high pressure gas filtration test rig has been built at CERC to study the performance and the possibility of removing particulates, acid gases and nitrogenous species simultaneously at high temperature and pressure in a ceramic filter coated with catalysts.

Biomass as a renewable energy source can be used for electricity generation, residential and home heating and the production of biofuels. Bulky biomass needs to be densified into wood pellets and are transported to final users. The pellets emit gases due to the degradation and decomposition that would accumulate within the storage space. Exposure to the gases is a serious health hazard to people who work around these spaces. The project conducted in the CERC is to investigate the off-gassing of wood pellets in controlled environment by experimentally identifying and establishing concentrations of gas species in the space of stored wood pellets in order to develop storage characteristics for pellets to minimize potential of self-heating and spontaneous combustion. Also, we are exploring new processes (e.g. steam explosion and torrefaction) to manufacture more durable pellets that can be stored longer and handled easier and safer.

Hydrogen Generation Section:

CERC High Head Laboratory has a continuous electrochemical reactor test station for complimentary work on the synthesis of fuels and novel fuel cell concepts. Our equipment in the High Head lab consists of a small pilot-scale continuous electrochemical reactor test station. This equipment is used for research on electro-synthesis (e.g. of formic acid from carbon dioxide) and on electrochemical power generation (e.g. direct liquid fuel cells).The SW corner of the High Head Lab of CERC accommodates two high pressure reactors in which the mechanism of the hydrogen generation through aluminum-assisted water split reaction will be studied using elevated temperatures and pressures.

- **Fuel Cell Lab**

The CERC Fuel Cell Laboratory contains specialized test stations, ancillary equipment and services for experimental work on fuel cells of up to 1 kW load capacity.

- **Clean Combustion Lab**

The rapid compression machine (RCM) will use the latest laser diagnostics techniques to elucidate the fuel air ratio of a directly injected partially stratified natural gas engine. The RCM will be used in conjunction with planar laser induced fluorescence (PLIF) to visualize the formation of a combustible mixture prior to ignition. The RCM is a simplified engine cylinder which only describes two engine strokes (or one shaft revolution) and it does so over a closed volume. The absence of intake and exhaust valves allows the study of the mixture formation without the complex air motion induced by valve action. The fundamental processes by which a combustible mixture is generated through both partial stratification and direct injection can then be studied, as can the interaction between the two fuel sources. The insight gained will allow further development of clean burning, partially stratified engines, which are believed to be the future of clean burning engine technology.

The development of the optically accessible methane steam reformer has taken place with the longer term aim of developing an optically accessible, internally reforming Solid Oxide Fuel Cell (SOFC) rig in which SOFC research can take place. An SOFC operates at between 750°C and 1000°C and is an extremely harsh environment in which to carry out experimental measurements. SOFC's are therefore seen as an application in which alternative measurement techniques can be utilized; in this case advanced laser diagnostics and Infra Red (IR) temperature measurement.

Laser diagnostic IR temperature measurement techniques have the advantage of being non intrusive whilst being able to offer greater levels of detail than currently possible using conventional techniques. Once the techniques have been perfected and validated the next stage is to integrate them in an actual SOFC. They should then offer an insight into the chemical and thermal processes taking place in a fully functioning SOFC.

- **Clean Burning Engines Lab**

The Clean Burning Engines Lab provides state of the art infrastructure for the support of three research engines. Services available to the engines include high capacity test cell ventilation; supercharged intake air; high and low pressure natural gas, diesel and gasoline fuel supplies; and an automatic safety system that includes hazardous gas detection. A central control system coordinates the engine services, and provides operators with feedback and command input through a touch-sensitive display screen. A comprehensive emissions bench offers real-time feedback on pollutant formation, as it continuously samples raw engine exhaust from the test cells individually. Each of the three test cells is equipped with a vibration isolating bed-plate, onto which a wide range of research platforms can be assembled. The current complement of engines includes a Ricardo Hydra single cylinder research engine; a Cummins ISX six cylinder diesel engine that has been adapted for research purposes; and will soon include a an optically accessible Ricardo Proteus engine.
Current research interests are focused realizing the clean burning potential of natural gas in applications that have traditionally been dominated by diesel engines. These interests are supported by ongoing investigations into various mixture preparation and ignition methods.

Current mixture preparation capabilities include ultra-lean, as well as partially and fully stratified charge fuelling. Ignition methods under investigation include spark ignition enhanced by a pilot fuel charge, as well as compression ignition by means of a diesel pilot.

- **New Fuels from Biological Processes**

The, lab focuses on the production of environmentally friendly fuels such as ethanol and hydrogen using waste lignocellulosics as feedstocks for the process. We use biocatalysis (reactions catalysed by enzymes or whole microbial cells) to conduct the required conversions under mild reaction conditions. The use of biocatalysis minimizes energy inputs to the process and allows for the production of a very pure product stream.

- **Reducing Energy Losses Lab**

In heavy oil upgraders, oil refineries and petro-chemical plants, energy efficieny declines with time on stream, as carbonaceous solids build up on heat transfer surfaces. This decline neccesitates burning of extra fuel, increasing carbon dioxide emissions, and also causes increased pressure drop for pumping, and process shut-downs. To improve energy efficiency, the mechanisms of formation of unwanted carbonaceous
deposits on heat exchange surfaces must be understood. Experimentation
is carried out to study the effects of fluid flow and phase behaviour, heat transfer, and chemical reactions such as coking, autoxidation and sulphide corrosion, on rates of deposit formation from heavy oils and petroleum mixtures in heat exhanger systems.

- **Gas Hydrate Technologies Lab**

In the Gas hydrate technologies laboratory we are constructing a special apparatus to study gas hydrate formation from natural gas; flue gases and fuel gases. The work with natural gas is related to our goal to develop technology for the transport and storage of natural gas in the solid hydrate form. The work with flue gases exploits the idea of utilizing gas hydrates for the separation of carbon dioxide from flue gases exiting power plants. A fuel gas mixture is a mixture of carbon dioxide and hydrogen and is from coal gasification or reforming natural gas followed by the shift reaction. Our work aims to develop the technology to separate hydrogen for use in fuel cells or turbines and carbon dioxide. In the above three applications a key requirement for the development of the technologies is the efficient contact between gas and water for the rapid formation of the gas hydrate crystal. Our apparatus is designed to exploit three gas/water contact configurations. Finally, the laboratory is equipped with a cold room for the development of a secondary apparatus that will allow the visual observation of gas hydrate crystal formation.

- **Renewable Energy Lab**

- **New Methods for Hydrogen Generation**

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