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CCRC Clean Combustion Research Center

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Pictorial representation of member nationalities in the Clean Combustion Research Center

Diversity at CCRC

Since its inclusion as a science, theories about combustion have come from all corners of the world. Early theories on combustion can be attributed to ancient Greeks who conceptualized combustion in terms of philosophy and metaphysics, or to the early Chinese, who described their first observations of autoignition. Ancient Indian civilizations used fired kilns to make utensils and other tools. Equal contributions can be attributed to European engineers, who mastered the idea of machines and engines running on combustion, opening the way to the industrial era. Americans and Russians scaled up from kinetic theories of gases to the most advanced combustion technologies. Important social and industrial transformations have been contributed from all the corners of the globe and all walks of life.

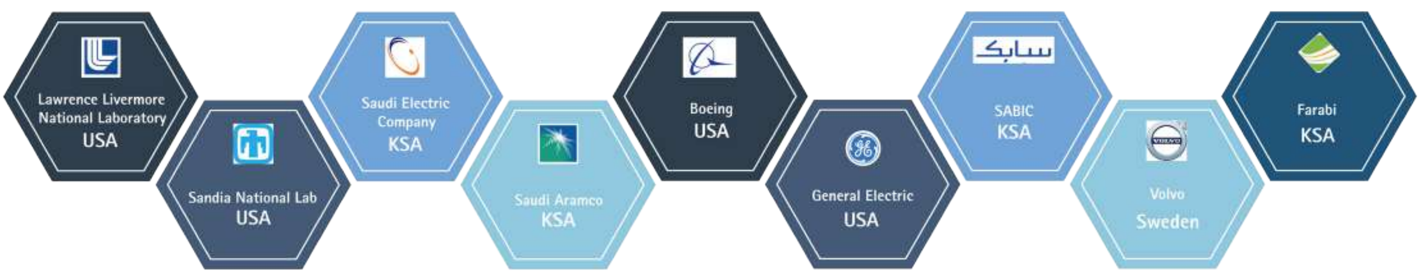
At CCRC we strive to rekindle this same spirit by bringing together the finest researchers worldwide. This energetic mixture of cultures, languages and ethnicities, working together towards the advancement of combustion science, not only seems to recreate the zeal of the past, but also ignites more exciting research than ever. A symbiotic relationship has been fostered among our researchers: Chemists and chemical engineers develop quantum chemistry and comprehensive combustion chemistry models. This, in turn, is utilized by mechanical engineers and mathematicians writing codes for reactive flow simulations. Their information is further applied by fundamental and engine experimentalists to design innovative experiments and gain further insight into the science of combustion.

To further encourage the spirit of diversity, CCRC has forged partnerships with leading academic, research and industrial organizations worldwide; these partnerships allow CCRC to develop with the latest research and recruit the best talent to support our growing research footprint.

This extraordinary mix of people and collaborations, skills and ideas from all over the world, has resulted in an atmosphere of cutting edge combustion research.

Academic Collaborators

Industrial Collaborators



KAUST high pressure combustion lab facility.

Studying Fuel Combustion Under Industrial Conditions

Fuel combustion plays a vital role in our daily life; it is the main source of energy for transportation in automobiles, aircraft and even rockets as well as energy production in gas turbines and steam boilers. Although those applications operate at high pressure (5-100 bar), most scientific research is based on lab-scale experiments conducted at atmospheric pressure.

As part of its interest in practical applications, the Clean Combustion Research Center (CCRC) at KAUST facilitates industrial high pressure scale test rigs for various fuel combustion purposes. It focuses mainly on understanding phenomena such as laminar and turbulent burning characteristics of flame and soot formation at high pressure and high temperature regimes.

HIGH PRESSURE COMBUSTION DUCT

One notable apparatus at CCRC is its high pressure combustion duct, which investigates high Reynolds number flames for understanding fundamental turbulence-chemistry interactions and soot formation. Compared to lab-scale experiment systems, this apparatus is unique in size and design. It is eight meters tall and weighs more than five tons, with an internal diameter of 400 mm. This duct allows the study of flames up to 1.5 meters long and characterized by Reynolds numbers higher than 20,000, while operating under pressures up to 40 bar. The test rig is surrounded by six windows to enable the viewing access required for laser diagnostics. The current setup incorporates planar laser-induced fluorescence (PLIF), particle image velocimetry (PIV) and laser-induced incandescence (LII) for measuring concentrations of OH, formaldehyde and polyaromatics, to enhance fundamental comprehension of turbulent flames. In the future, Raman spectroscopy and Rayleigh scattering will be integrated to better understand soot emissions from turbulent flames.

Wesley Boyette is a PhD student at KAUST who has been working on constructing and operating the high pressure duct for six years. He says: "Our high pressure combustion duct is one of a kind; it's attracting researchers from around the world and opening the door for international collaboration." He added: "We're currently collaborating with Vanderbilt, Sydney and Cambridge Universities, conducting experiments that utilize their fuel burners in our high pressure duct."

We spoke with Harshini Devathi, a visiting PhD student from Vanderbilt University in the US, who told us: "I came to Saudi Arabia and KAUST to test my burner in their high pressure duct; it's difficult to access such a fully developed facility for high pressure experiments anywhere else."

Images of flames from the high pressure combustion duct under different pressure ranges.

High pressure combustion duct.

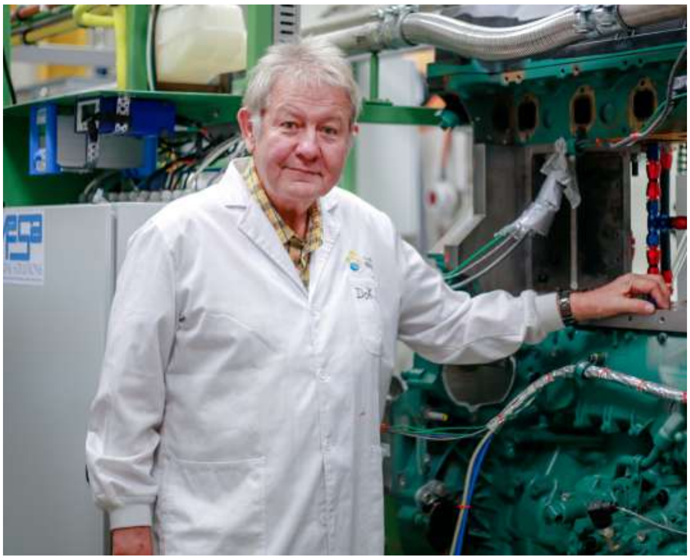
HIGH PRESSURE, HIGH TEMPERATURE TEST RIGS

The CCRC is pushing lab facility capabilities beyond current limits by setting up high pressure, high temperature test rigs; the high pressure/temperature corrosion test chamber is one such example. This chamber tests the resistance of various materials to corrosion at elevated conditions, like those encountered in gas turbines. The setup reaches up to 900˚C and 10 bars, and the test can be conducted continuously for 100 hours. This facility is being optimized by CCRC researchers to maximize testing capability to 20 bars and 2000 hours of operation.

The testing chamber is currently utilized in collaboration with General Electric (GE), to test the effect of harsh environments, like the one in industrial operation on gas turbine blade material. The material is exposed directly to a flame produced from Arabian extra light (AXL) fuel under six bars and 900˚C continuously for 100 hours.

Another interesting model in the high pressure combustion lab is the high pressure, high temperature autoignition test rig. This is a new version of the high pressure combustion duct; it can heat the air surrounding test fuels with temperatures in excess of 1000˚C. This rig promises improved comprehension in autoignition combustion experiments. Start-up will begin in the first quarter of 2018.

Interview with Robert Dibble



Professor Robert Dibble's unconventional introduction to the combustion world began with an energy crisis in the US during the 1970's. Previously, his research interests had been in the development of lasers for use in chemical manufacturing. Due to the energy crisis, new funding for NSF research grants opened the doors for post doc positions, and he began his lifelong career in combustion at Imperial College. Following his time at Imperial College, Dr. Dibble returned to the US and began working at the newly-formed Sandia National Labs. During that time, air quality was one of the major challenges facing the combustion industry. NOx emissions in particular, were causing significant pollution problems. Dr. Dibble's background in lasers opened the way to further understand the combustion process and reduce pollution problems from NOx.

Through his pioneering efforts, and those of his colleagues, many of the problems associated with NOx emissions have been greatly reduced. Dr. Dibble's focus has now shifted to the newest challenge in combustion: CO2 emissions. A number of different tactics for combating the rise in global CO2 have been undertaken; one solution Dr. Dibble has been working on is carbon capture and storage.

The fuels of the future, Dr. Dibble predicts, will be carbonless, or carbon neutral. One of the innovations he sees being considered in Norway is using NH3 in gas turbines. Another possibility is the use of formic acid, which can be a CO2-neutral fuel. He points out that biofuels have been seriously studied for the past 20 years, but due to its challenges, progress has been limited. Furthermore, the cost of renewable energy is greatly decreasing. This low cost energy source is opening the doors for e-fuels. E-fuels convert electrical energy into fuel; they can be used in various ways and made during times when renewable energy is available.

Based on the current challenges of combustion, Dr. Dibble theorizes that the greatest impact that CCRC can have on the future of combustion will be increasing combustion efficiency to reduce overall CO2 emissions; CCRC has several projects that focus on this--in particular, the development of the next generation of engines. He predicts that the future will see an increase in the number of studies on oxyfuel combustion.

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