

# GLOBAL Gas Turbine News

ATLANTA, GEORGIA USA • ASME INTERNATIONAL GAS TURBINE INSTITUTE

## Turbo Expo 2009 Keynote Theme Announced



**TURBO EXPO**  
Gas Turbine Technical Congress & Exposition  
Presented by the International Gas Turbine Institute



EXECUTIVE CONFERENCE  
CHAIR  
BARRY NICHOLLS

**IGTI** is pleased to announce the theme of the Turbo Expo 2009 keynote address, *Gas Turbine Technologies: Meeting Complex Global Challenges*.

Executive Conference Chair Barry Nicholls, Vice President of Siemens Power Systems Sales, Siemens Power Generation, Inc., helped direct the focus of the keynote. IGTI asked Nicholls to elaborate on the theme:

**Q:** Why do you think the keynote topic "Gas Turbine Technologies: Meeting Complex Global Challenges" is so relevant/important to the gas turbine industry right now?

**A:** Today we live in a constant and rapidly changing global environment rooted in the surging information age. As a result, to keep customers satisfied, development and implementation horizons are decreasing at the same time the level of performance (power and efficiency) must continuously increase. What we currently face with gas turbines is an analogous situation to Moore's law for transistors and other computer hardware, perhaps a bit less aggressive though! The only way to meet this challenge is with aggressive technology innovation and implementation lead by excellent employees and fundamentally strong customer interaction. When you add to this environment a significant (and growing) variation and cost in global fuel sources, power plant flexibility requirements and regionally stringent emission legislation, you run into a situation where it is "mission critical" to not only have technology innovation but also to create a suite of interchangeable proven technologies for a platform gas turbine operation approach. As an example, we consistently find ourselves at the edge of temperatures, oxidation and corrosion limits of turbine materials, and the challenge is how to develop and implement step changes in these systems and integrate their design into the turbine with low risk across a worldwide fleet of engines.

**Q:** Aside from energy supply & cost, what are additional challenges facing gas turbine engineers in the future?

**A:** Certainly you might say economic volatility and the possibility for a global slowdown have many engineers questioning future uncertainties, but I'm quite certain that's true with most of us at the moment. The next topic of discussion would probably be: what's the future of gas turbines in a world that talks so much about renewable power? There is a very simple answer to that; power demand continues to grow and while renewables are a great source of energy going forward, they simply will not significantly lessen the demand for clean gas turbine technology which we see as the preferred option to

fill the global power gap in the coming years. Another possible concern is political uncertainty in the area of carbon legislation and emission controls, a lot hangs in the balance right now as to how this legislation is approached and executed and the effect on the global energy portfolio balance between gas turbines, coal, nuclear and renewables. A third concern is staffing; it is becoming more and more difficult to find and retain qualified engineers. Some concerns I've heard lately coming from the engineering community is "who's going to do all this work?" It's something we still don't have a long-term answer for, since the trend of university graduates is currently not in favor of engineering.

**Q:** What are some energy-efficient, "clean" technologies currently in development in the gas turbine industry?

**A:** A lot of emphasis is being placed on high hydrogen fuels (pre-combustion carbon sequestration of gasified coal [IGCC]), and carbon neutral bio fuels in low emission applications by the department of energy. We see these as areas of growth in the future and the right thing to do, so we are actively participating with the DOE in these programs and on our own. We also see technology breakthroughs coming in the areas of combustion and turbine engineering, materials and post combustion gas treatment that will be cost effective game changers for emissions, power and efficiency.

**Q:** What role does Turbo Expo play in shaping R&D solutions for industry challenges? Is there anything that Turbo Expo should do to expand its role in 2009 and beyond?

**A:** Turbo Expo is a great forum to get the major players in the gas turbine world together and have technical discussions and collaborations. It allows engineers from the power generation side to attend talks by aero engineers and vice versa; this is a good way to stimulate bottom line innovation. As an OEM, we would always like to see increased end user attendance at the Turbo Expo event. \*

### IN THIS ISSUE...

Calendar of Events

2

Aircraft Engine  
Thermal Management:  
The Impact of Aviation  
Electric Power Demands

2-3

Compact Gas Turbine  
Combustion Research

4-5

Opportunity Fuels  
and Combustion

5-6

Professional Development

7

# Aircraft Engine Thermal Management: The Impact of Aviation Electric Power Demands

By William D. Gerstler, *Senior Engineer, Thermal Systems Lab, Energy & Propulsion Technologies, GE Global Research Center* and Ronald S. Bunker, *Principal Engineer, Thermal Systems Lab, Energy & Propulsion Technologies, GE Global Research Center*

Traditionally, thermal management of aviation gas turbine engines has been concentrated in the core of the engine. Actively or passively cooled regions in aircraft engine gas turbines include the high-pressure turbine stationary vanes and rotating blades, the shrouds bounding the rotating blades, the combustor liners and flame holding segments, and the exhaust nozzle / after burner system. Collectively these components are referred to as the hot gas path. Such engines additionally cool the interfaces around the immediate hot gas path using the secondary airflow circuits of the turbine wheel spaces and outer casings. The secondary fluid flow systems also extend well beyond the core region including thermal management of the lube oil and bearings, deicing within the compressor, and active clearance control measures. Conventional cooling technology, as applied to gas turbine engine components, is composed of internal convective cooling, external surface film cooling, materials and coatings selection,

thermal-mechanical design at both the component and system levels, and selection and/or pre-treatment of the coolant fluid. Together these technologies define the conventional thermal management capabilities and limitations in today's gas turbines.

This traditional view of thermal management continues to face many technology challenges today due to the need for higher efficiencies with lower specific fuel consumption. One manner air-framers are improving fuel efficiency is replacing traditional systems with those that operate using electrical power. For example, power from engine compressor bleed air is traditionally used for multiple purposes including conditioned cabin air, pneumatic actuation, and de-icing. Using bleed air as an energy source has several negative effects in regard to fuel usage. It removes air from the engine, thus directly lowering engine efficiency. In addition, the piping and all the other pneumatic components are heavy, further increasing aircraft fuel usage. Electric power extracted from the engine shaft can be used to energize components that serve the same function as those powered by the bleed air. For instance, the environmental control system (ECS) traditionally powered by the bleed air can be operated using a high efficiency electric motor. Electrical based components can similarly be used to replace hydraulic-based components that require hefty tubing, pumps, and significant amounts of fluid. Finally, the operation of increasingly powerful digital avionics

## CALENDAR OF EVENTS

### JANUARY 19-23, 2009

**Ultra Low NOx Gas Turbine Combustion Course**  
Weetwood Hall Conference Centre & Hotel  
Otley Road, Leeds, UK

Organized by the University of Leeds, this course is designed for combustion designers in gas turbine manufacturers; operators of modern, low NOx electrical generation systems, including combined cycles; automotive emissions engineers and environmental legislators and regulators. For more information visit [www.engineering.leeds.ac.uk/cpd](http://www.engineering.leeds.ac.uk/cpd) or email: [cpd@engineering.leeds.ac.uk](mailto:cpd@engineering.leeds.ac.uk).

### MARCH 5-6, 2009

**The Gas Turbine: Principles and Applications Short Course**  
Amsterdam Marriott Hotel  
Amsterdam, Netherlands

Calling design and development engineers, maintenance and reliability engineers, project managers, Q&A personnel and mechanical engineers working with gas turbines! This two-day course is about efficient evaluation of gas turbine performance for the selection and application of the right engine for the job. Visit [http://www.asme.org/Education/Europe/Courses/Gas\\_Turbine\\_Principles](http://www.asme.org/Education/Europe/Courses/Gas_Turbine_Principles) for more details.

### June 6, 2009

**Basic Gas Turbine Metallurgy & Repair Technology Workshop**  
World Center Marriott Resort  
Orlando, FL USA

Held in conjunction with Turbo Expo and instructed by Lloyd Cooke and Doug Nagy, Liburdi Turbine Services.

### June 6-7, 2009

**Physics-Based Internal Air System Modeling Short Course**  
World Center Marriott Resort  
Orlando, FL USA

Held in conjunction with Turbo Expo and instructed by Dr. Bijay K. Sultanian, Siemens Energy, Inc.

### June 6-7, 2009

**Gas Turbine Aerothermodynamics & Performance Modeling Short Course**  
World Center Marriott Resort  
Orlando, FL USA

Held in conjunction with Turbo Expo and instructed by Syed Khalid, Rolls-Royce North America, this interactive course includes tutorial sessions.

### June 7, 2009

**Film Cooling & Technology for Gas Turbines Workshop**  
World Center Marriott Resort  
Orlando, FL USA

Held in conjunction with Turbo Expo and conducted by VKI (Von Karman Institute) and IGTI.

### JUNE 8-12, 2009

**ASME Turbo Expo 2009**  
Orlando World Marriott Resort and Convention Center  
Orlando, Florida USA

IGTI's flagship event comprises a major gas turbine conference and exhibition. This 2009 event will be held at an all-inclusive resort with golf course.

### AUGUST 2-5, 2009

**45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit**  
**7th Annual International Energy Conversion Engineering Conference (IECEC)**  
Colorado Convention Center  
Denver, CO

The objective for the Joint Propulsion Conference is to identify and highlight the propulsion systems, components, and technologies required to enable the next generation of aerospace vehicles. The IECEC conference provides a forum to present and discuss engineering aspects of energy conversion technology, advanced energy and power systems, devices for terrestrial energy systems and aerospace applications, and the policy, programs, and environmental impact associated with the development and utilization of this technology.

### FEBRUARY 2010

**13th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC-13)**  
Hawaii – more details TBA

This conference deals with all aspects of transport phenomena and dynamics in rotating machinery, including research, design, manufacturing, and operation. It provides a forum for presentation of new and innovative technologies as well as free exchange of ideas among the world leaders in rotating machinery.

### JUNE 14-18, 2010

**ASME Turbo Expo 2010**  
Scottish Exhibition & Convention Centre  
Glasgow, Scotland

IGTI's flagship event comprises a major gas turbine conference and exhibition.

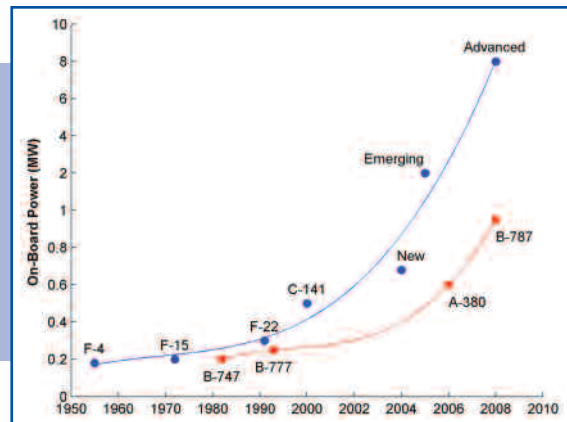
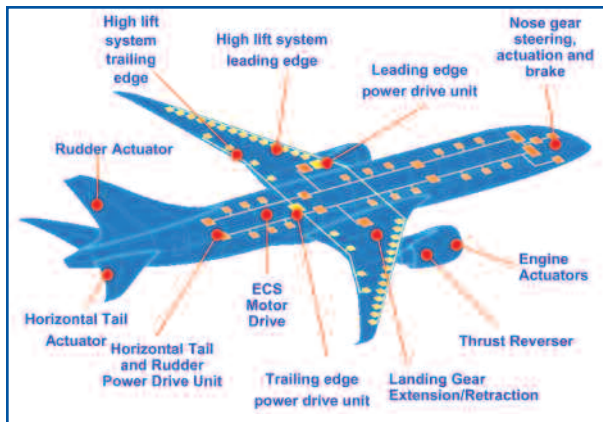
### AUGUST 7-13, 2010

**14th Int'l Heat Transfer Conference (IHTC)**  
Omni Shoreham Hotel  
Washington D.C., USA

## TRAVEL ASSISTANCE:

IGTI is offering financial assistance for a limited number of early career engineers to attend Turbo Expo 2009. Please visit <http://igti.asme.org> for more details.





requires the availability of additional on-board power. Figure 1 shows various potential electric powered aircraft systems. While fuel efficiency is one driver towards more electric aircraft, there are others including decreased cost associated with maintenance and installation.

The projected growth in on-board electric power is significant for both commercial airliners and military aircraft as depicted in Figure 2. For example, the Boeing 777 introduced in the mid-1990's used about 200kW of on-board electric power, but the new Boeing 787 Dreamliner® is expected to demand nearly 1MW. This expansion of electric power demand is accompanied by a doubling of the power extraction to thrust ratio (rated kVA/Klbs) for the engines. The increase in on-board electric power demand is projected to be even higher for military aviation, driven by avionics, actuator drives and controls, and weapons systems advances. A key enabler to achieving the increased on-board electric power is thermal management. The generators, power electronic converters/inverters, motors, and many of the digital electronic devices must be designed with very high power density for aviation applications. If the losses are not removed the electrical component can be destroyed due to overheating. The effectiveness of the thermal management system is the limiting factor in determining the achievable power density.

In the past, electric power thermal management was often achieved without much regard to the propulsion system and without significant optimization with the electric power system. In light of this, perhaps the single most challenging aspect of the explosive growth in on-board electric power is the need for integration of propulsion, power, and thermal management. The greatly distributed nature of the systems requiring electric power, coupled with their

increasing power densities and operational temperature limitations, leads to the inevitable need for localized and diverse thermal solutions. Heat generated must either be dissipated/rejected to the surroundings, transported for use elsewhere in the airframe/engine, converted to other energy modes, or stored in on-board media for later use or disposal. Other aircraft trends such as the use of composite fiber materials, decreased volumes of on-board fuel and oil, and the desire to minimize the use of any technology that disturbs the aerodynamic efficiency of the aircraft and engine (i.e. air-to-liquid and air-to-air heat exchangers) increase the difficulty in finding adequate thermal management solutions. Technologies that will play important roles in these new challenges include advanced materials for heat shielding and high temperature power electronics, heat pipes and their related technologies, advanced heat sinks including those directly integrated with electronic modules and/or those that employ micro-channel cooling, synthetic jet and spray/mist jet cooling, nano-fluids, and phase change modules. Effective integration of these thermal management technologies into the overall system design will be crucial to successful future aircraft. ✨

## GTUS08 Holds Successful Co-location with Turbomachinery Symposium

**GTUS** GAS TURBINE USERS SYMPOSIUM  
Presented by the International Gas Turbine Institute



Delegates at the 2008 edition of the ASME Gas Turbine Users Symposium found themselves in a new venue. For the first time, GTUS co-located with Texas A&M's Turbomachinery Symposium, September 8-11 at the George R. Brown Convention Center in Houston.

The new co-location was deemed a success by GTUS Chair, Patrick Campbell of GE Oil & Gas. "We saw resurgence in attendance," Campbell said, "demonstrating this is an appropriate symbiotic relationship, bringing the driven equipment and gas turbine drivers under one roof."

Gas turbine users could attend sessions under four tracks: Design, Operation & Maintenance, Advances, and Environmental Issues. Attendee feedback indicates that *Introduction to Gas Turbines* was among the sessions that were quite popular.

This was a new tutorial, delivered in three parts and provided a comprehensive overview into the function, performance characteristics, and typical operational issues for industrial gas turbines. Case studies as well as discussion were also incorporated by the four-man team of expert instructors.

Another highlight of the week was the annual networking dinner, generously sponsored by GE Oil and Gas. In conjunction with GTUS, IGTI also presented two full-day, well-attended workshops, *Combustion Dynamics in Gas Turbine Power Plants* and *Basic Gas Turbine Metallurgy and Component Repair*.

David Mucz, Manager, Business Operations with Alliance Pipeline, Ltd., in Calgary, Alberta, Canada, was introduced as the new GTUS Chair during the planning meeting at the conclusion of the event. Mucz will serve a two-year term as Chair. ✨

# Compact Gas Turbine Combustion Research

By Dr. Joseph Zelina, *Air Force Research Laboratory, Propulsion Directorate*

Brayton cycle combustion systems have remained nearly unchanged in their basic swirl-stabilized design for nearly 50 years. In recent times, novel concepts are emerging that have the potential to improve combustion system performance. One concept called the trapped vortex combustor (TVC) was conceived in the early 1990's as a possible combustor design that can provide improved operability and emissions performance. The Air Force Research Laboratory (AFRL) is investigating novel combustion concepts that include TVC, and more aggressive high-g ultra-compact combustors (UCC). Both the TVC and high-g concepts have shown promise in providing a reduced-volume, highly efficient and stable combustor. These short combustors enable the use of a UCC in a revolutionary propulsion system that operates on a highly efficient near constant temperature (NCT) cycle, or reheat cycle. Such a propulsion system called the inter-turbine burner (ITB), could enable power extraction, thrust augmentation, reduced fuel burn, and specific thrust (ST) improvements.

**Trapped Vortex Combustion:** As opposed to conventional swirl-stabilized combustion systems where the flow is stabilized aerodynamically (see Fig. 1a) a TVC employs cavities to stabilize the flame

(Fig. 1b). A TVC mechanically anchors a pilot recirculation zone by holding it within a specially designed cavity over a wide range of flow conditions. Primary fuel and air are injected directly into the cavities such that the vortex is reinforced. Experiments indicated that the TVC can reduce pollutant emissions by as much as 60% and improve operability even though the combustor volume is reduced by almost 70% for both large-size and small-size engines. Building on the lessons learned from TVC, a more aggressive concept using high gravity (g) combustion, called a UCC, is explored that can provide even greater engine weight and volume reductions and become an enabling technology for reheat cycle engines (Zelina, J., Shouse, D. T., Stutrud, J. S., Sturgess, G. J., and Roquemore, W. M., "Exploration of Compact Combustors for Reheat Cycle Aero Applications," AMSE IGTI GT2006-90179).

**High Gravity (g) Combustion:** In the high-g UCC concept, a cavity runs around the outer circumference of the turbine inlet guide vanes (TIGV), as seen in Fig. 2. The fuel is introduced into this cavity. Aligned with this cavity, on each vane, is a radial cavity that extends to the inner platform. The flow within this cavity will be swirled to generate high "g" loading ( $\sim 1000$  g's) and improve mixing. The idea is to burn rich in the circumferential cavity, allowing much of the required combustion residence time to take place in the circumferential direction of the engine, rather than the axial as is done conventionally. The intermediate products of combustion are transported into the radial cavities in the vane surfaces where combustion continues at a reduced equivalence ratio as the mainstream air is entrained into the wakes. Finally, across the leading edge of the vanes, again in a circumferential orientation, there may be a minimum blockage flame-holder (if necessary) where products will be entrained and distributed into the main flow. Additional air, fed from the interior of the vanes, is introduced into the radial cavities for cooling and combustion.

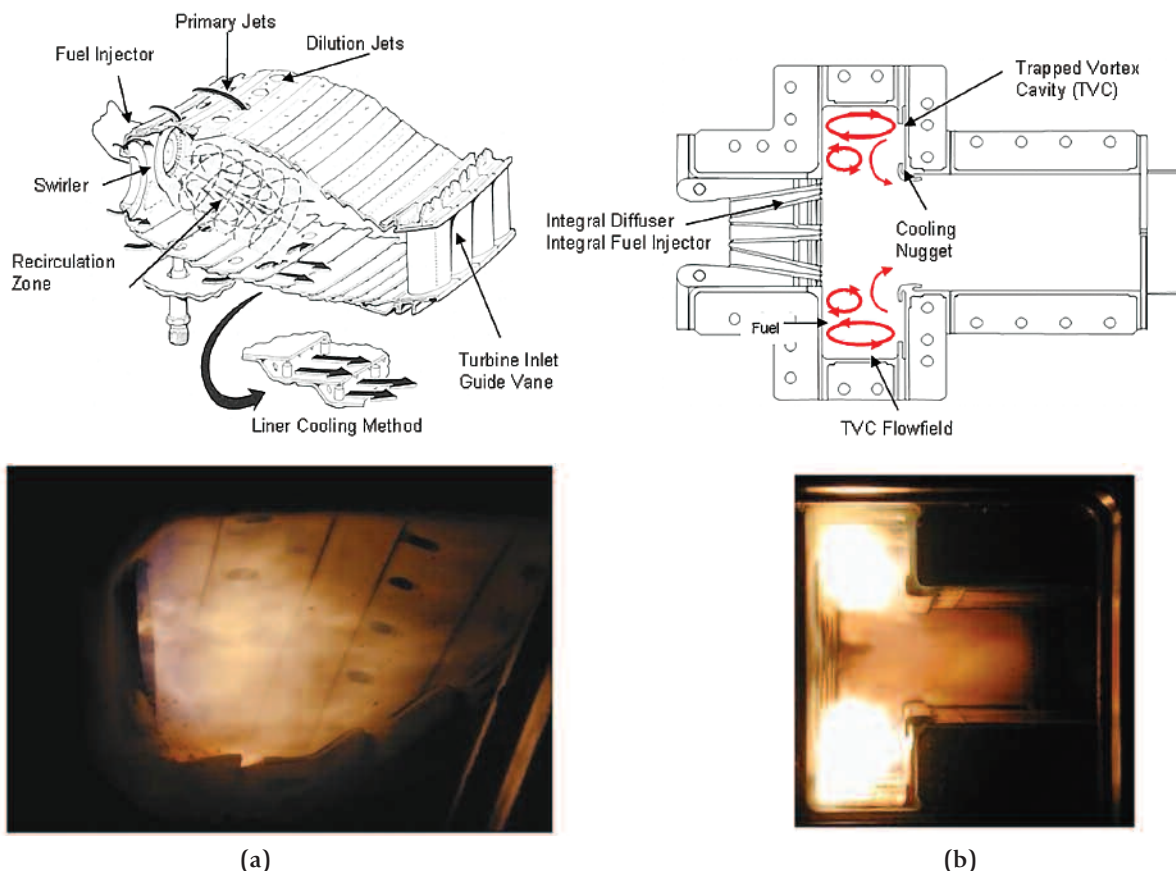


Figure 1: Schematics of: (a) Conventional Swirl-Stabilized Combustor and (b) Trapped Vortex Combustor.

Functionally, the circumferential cavity may be regarded as a primary zone, the radial cavities as constituting an intermediate zone, and the circumferential strut flame-holder as the dilution zone. All combustion is intended to be completed prior to any flow turning and acceleration caused by the turbine inlet guide vanes. Swirl from the compressor may be used to drive the swirl in the circumferential cavity. Using the compressor swirl will negate the need for a stator ahead of the combustor, further shortening overall system length.

Future aircraft systems will inevitably require more power extraction capability to support weapons systems, sensor suites, avionics, and controls. Now that substantial engine length reduction is realized with the UCC concept, this type of combustion system enables the use of an ITB between the high pressure turbine (HPT) and low pressure turbine (LPT) spools of the engine. The gas turbine now operates as a reheat cycle which can provide large amounts of LPT power extraction with only a 200 °F – 500 °F temperature rise across the ITB.

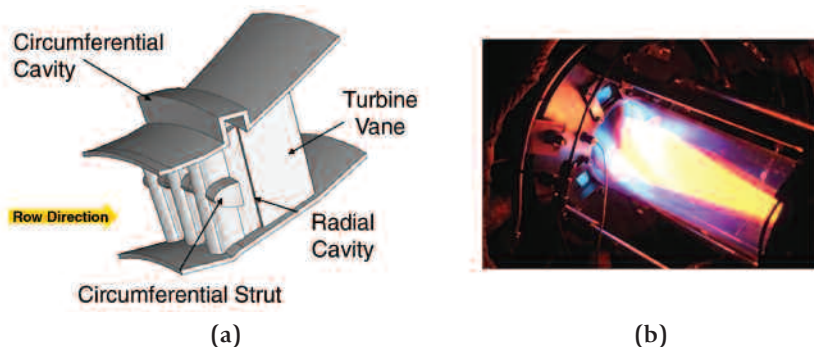


Figure 2: Ultra-Compact Combustor Concept.  
(a) Schematic Showing Integral Circumferential Cavity and Turbine Vanes and (b) Ultra-Compact Combustor in Operation.

Other system benefits include reduced engine cross-section while maintaining thrust or power output. Fuel can be axially staged by independent control of main combustor and ITB to meet power requirements and potentially reduce pollutant emissions. Both combustion chambers can be operated at substantially lower fuel-to-air ratios than a single chamber, which enables the use of conventional metallic components and increased turbine life by as much as three orders of magnitude! For ground-based, marine, and turboshaft engines, the combustion system can be tailored to meet low CO and UHC emissions and reduced fuel burn by operating only the main combustor at low-power conditions.

AFRL is in detailed design phase of a UCC combustor rig that utilizes a single-sided TVC where the TIGV is integrated into the main flowpath below the TVC. The rig will have optical access to visualize the flow out of the TVC to the vanes. The rig will be designed with versatility to allow for different vane designs, cavity configurations, materials, and vane cooling schemes. Based on successful tests of both TVC and integrated vane designs, this test will determine concept feasibility in a realistic engine environment where operating conditions will be as high as 1100 F and 200 psia inlet temperature and pressure respectively. \*

## Opportunity Fuels and Combustion

By Colin Etheridge, Senior Consulting Engineer, Solar Turbines Incorporated and Rainer Kurz, Manager, Systems Analysis, Solar Turbines Incorporated

Industrial gas turbines allow operation with a wide variety of gaseous and liquid fuels, while maintaining very low emissions. Gaseous fuels are not limited to traditional, pipeline quality natural gas, but may include opportunity fuels such as gas available at oil and gas fields, or products of industrial processes. Today, many applications require lean pre-mix systems to achieve the low emissions necessary.

Lean pre-mix combustors require to thoroughly mix fuel gas and air at the required mixture ratio prior to the actual combustion. This allows gas turbines to produce the very low levels of NO<sub>x</sub>, CO and unburned hydrocarbon (UHC) emissions seen today. Because a flammable mixture exists prior to the actual combustion, additional attention has to be paid to such fuel related properties as autoignition delay time, and flame speed. For a given lean pre-mix combustion system, ignoring flashback, autoignition effects, and combustion instabilities, emissions will vary as a function of the fuel because of differences in stoichiometry and adiabatic flame temperature.

In practice, lean pre-mix injector designs will have to be tailored to meet the various characteristics for any hydrogen rich fuel and take into consideration a number of factors which include:

- Primary zone stoichiometry for:
  - NO<sub>x</sub> emissions
  - CO emissions
  - Combustion stability
- Flame speed
- Autoignition delay time
- Injector pressure drop
- Combustor oscillations

The *laminar flame speed*, also called flame velocity, or burning velocity, is defined as the velocity at which unburned gases move through the combustion wave in the direction normal to the wave surface. A key point here is that the flame speed does not vary linearly between the respective pure values of the mixture constituents. For example, the addition of H<sub>2</sub> to CH<sub>4</sub> does not have a significant impact upon the flame speed until H<sub>2</sub> is the dominant constituent of the mixture. Adding diluents, like CO<sub>2</sub>, lead to a flame speed lower than for the non-diluted mixtures, even if the temperature is maintained by increasing the equivalence ratio. Flame propagation velocity is also strongly influenced by the fuel/air mixture ratio; the leaner the mixture the lower the velocity.

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## Opportunity Fuels and Combustion ... continued from page 5

However, most issues are related to the *turbulent flame speed*, which depends, besides the laminar flame speed, also on the turbulence levels of the gases in question. In particular, data show that as the turbulence intensity increases, the turbulent flame speed initially increases, then asymptotes to a constant value, and then at very high turbulence intensities begins to decrease. For a given turbulence intensity and a given burner, fuels with higher laminar flame speeds should have higher turbulent flame speeds. However, turbulence intensity and laminar flame speed alone do not capture many important characteristics of the turbulent flame speed. Two different fuel mixtures having the same laminar flame speed, turbulence intensity and burner can have *appreciably* different turbulent flame speeds depending on the diffusion characteristics of the species involved.

If the flow velocity in the combustor exceeds the flame propagation velocity, then flameout could occur. If the flame propagation velocity exceeds the flow velocity, then flashback within the premixing injectors could occur that can cause damage by overheating the injector tips and walls. To maintain flame stability at a point, the velocity of the fuel-air mixture must be within the flame-propagation speed to prevent flashback.

*Autoignition* is a process where a combustible mixture spontaneously reacts and releases heat in absence of any concentrated source of ignition such as a spark or a flame. Rather than the flame propagating upstream into the premixing section, autoignition could cause the spontaneous ignition of the mixture in the premixing section. Leaner mixtures tend to have a longer delay time, while higher mixture temperatures and higher pressures tend to shorten the delay time. In a lean premix injector, the flow velocities thus have to be high enough to avoid autoignition inside the injector at the prevailing temperatures. Increasing the content of heavier hydrocarbons in an associated gas leads to a decrease of delay time. This is mainly caused by the non-symmetry of all higher hydrocarbons: Heavy hydrocarbons can be attacked much easier than methane molecules, resulting in reduced ignition delay times.

In general, the characteristic kinetic times decrease with the addition of hydrogen, with the lowest times (and hence faster chemical kinetics) corresponding to mixtures of CO and H<sub>2</sub>. The longest times (and hence slower chemical kinetics) are attributed to the mixtures containing mostly methane. In general, few data are available for specific mixtures, and engine specific tests are often necessary to avoid problems.

Another important parameter is the *ratio of flammability limits*. In the combustor, the fuel and air must be continually burned to keep the engine running. When the flame in the combustor is extinguished it is called a flameout or blowout. The fuel to air ratio changes with the engine load, as described earlier. In order to prevent flameout the combustor must support combustion over a range of fuel to air ratios. Each fuel composition has its own flammability range (Ratio of Flammability Limits). If the engine required fuel to air ratio range is equal to or larger than the fuel flammability range, then at some point the engine will experience flameout and will not be able to operate at that point. Knowing the ratio of flammability limits allows a decision whether the fuel composition has a broad enough flammability range to support combustion for all operating points of the engine.

The *ratio of flammability limits* is defined as the upper flammability limit divided by the lower flammability limit. The upper flammability limit is the maximum fuel percentage (volumetric) mixed with air that will still light and burn when exposed to a spark or other ignition source. The lower is the minimum fuel percentage to sustain combustion. Different gases have different ranges of flammability. Hydrogen, for example, will burn with as little as 4 percent fuel and 96 percent air (lower limit) and as much as 75 percent fuel and 25 percent air (upper limit) at ambient pressure and temperature. Outside of this range (less than 4 percent or more than 75 percent fuel) the hydrogen-air mixture will not burn. Therefore hydrogen has a ratio of flammability limits of 75/4 equal to 18. On the other hand a typical coal gas has a ratio of 13.5/5.3 equal to 2.5. Coal gas typically contains methane, CO<sub>2</sub>, and CO. CO<sub>2</sub> is not combustible. Therefore, if the coal gas contains too much CO<sub>2</sub> the flammability range will decrease and this ratio of flammability limits will decrease as well.

The different reaction kinetics of different fuel gases impact combustion dynamics. Different fuel properties of gases with higher amounts of heavier hydrocarbons, carbon monoxide, or hydrogen have to be evaluated regarding the impact on the resistance of the combustor to oscillations.

Fuel issues are not limited to combustion itself. Potential hazards associated with fuel, including flammability, detonation limits, and autoignition temperatures must be considered inside and around the engine in case of unintentional fuel leakage. Turbine enclosures are usually equipped with gas detectors, and the enclosure ventilation system is optimized to avoid accumulation of leaked gases. Low molecular weight gases, which rise rapidly, may be trapped in high dead spots in the enclosure, while heavy gases tend to accumulate on the ground or in low spots. In case of leakage, accumulation above the flammability limits must be avoided. For non-luminous gas fires (especially hydrogen), fire detection may be difficult. Negative Joule Thompson coefficients will cause the fuel gas temperature to rise during isenthalpic expansion (for example through a leak), which may result in an explosion if autoignition temperatures are reached. This is a special concern with hydrogen rich fuels. Toxic gases, especially the odorless ones, require special safeguards against leakage.

The quality and composition of fuel burned in a gas turbine impacts the life of the turbine, particularly its combustion system and turbine section. The impact of physical and chemical characteristics of gas fuels for gas turbines were linked with combustion characteristics, and the resulting concerns. \*

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### ABOUT IGTI

*IGTI is an institute of ASME. For more info on IGTI's conferences and other membership benefits, visit <http://igti.asme.org>.*



# PROFESSIONAL DEVELOPMENT

*IGTI and the Professional Development Committee are hosting two courses and two workshops preceding the opening of "Turbo Expo 2009" in Orlando, Florida. Don't miss the unique opportunity to participate in these highly focused training programs in four specific topic areas. To register or for more information, visit <http://asmeconferences.org/TE09/ShortCourses.cfm>*

**Saturday, June 6, 2009:**

## **Workshop I: Basic Gas Turbine Metallurgy and Repair Technology Workshop**

*Instructed by Lloyd Cooke and Doug Nagy, Liburdi Turbine Services*

This workshop will explain super-alloy materials, component damage experienced from service exposure, techniques used to analyze the remaining life of components removed from service, protective coatings, component repair technologies, and quality assurance of repairs. The workshop includes many case study examples and the last section is devoted to a workshop where attendees develop component repair solutions. Participants may submit questions in advance regarding repair issues faced in their jobs.

### **HIGHLIGHTS**

- The workshop provides answers to common questions and issues for engine support staff
- What makes super-alloys especially suited for gas turbine components
- How do the different damage mechanisms affect the component - oxidation, corrosion, erosion
- How are high cycle fatigue, low cycle fatigue damage caused, prevented, and repaired
- What are the various heat treatments used in repairs, and why are they important
- What are the advantages, disadvantages of the many types of protective coatings
- What are the critical quality control steps in component repair
- How can you reliably extend the service life of these valuable components

**Saturday & Sunday, June 6-7, 2009:**

## **Workshop II: Physics-Based Internal Air System Modeling**

*Instructed by Dr. Bijay K. Sultanian, Siemens Energy, Inc.*

The overall purpose of this course is to develop a clear understanding of the underlying flow and heat transfer physics and the corresponding mathematical modeling and robust solution techniques for various components of an internal air flow system designed for cooling and sealing of critical parts of modern gas turbine engines.

After completing this course, participants should be able to:

1. recognize flow and heat transfer physics of various components of gas turbine internal air systems
2. design more accurate and solution-robust internal air flow network models
3. detect input and modeling errors in their flow network models
4. interpret results from their models for design applications
5. significantly improve their engineering productivity and company's design cycle time

**Saturday & Sunday, June 6-7, 2009:**

## **Workshop III: Gas Turbine Aerothermodynamics & Performance Modeling**

*Instructed by Syed Khalid, Rolls-Royce North America*

This workshop will provide review and reinforcement of relevant thermodynamic and aerodynamic concepts as applied to gas turbine engines, and performance calculation methods.

Participants will work out typical problems in the class during recitation sessions facilitated by the instructor. The course material has been evaluated by the Department of Mechanical and Aerospace Engineering of North Carolina State University.

After completing the course the participants will be able to:

1. apply aerothermodynamic concepts to the analysis of gas turbine engines
2. analyze turbomachinery velocity diagrams and relate those to thermodynamic parameters. Learn about the degree of reaction and the radial equilibrium equation.
3. become familiar with the discipline of operability and combustor characteristics.
4. analyze cycle analysis problems in class on integrating the component performances to get the overall engine performance. Problems include both aircraft engine and shaft power cycles.
5. comprehend:
  - i) the method of sizing the critical flow path areas at the design point
  - ii) the method of satisfying conservation laws to achieve cycle balance at off-design
  - iii) the technique of the multivariable solver used in cycle models
  - iv) the various engine cycles in the power generation field

**Sunday, June 7, 2009**

## **Workshop IV: Film Cooling & Technology for Gas Turbines**

*Co-sponsored by VKI (Von Karman Institute) and IGTI*

IGTI is proud to be partnering with the von Karman Institute to offer a one day workshop modeled from one of their week long lecture series on Film Cooling. VKI is a non-profit international educational and scientific organization, hosting three departments (aeronautics and aerospace, environmental and applied fluid dynamics, and turbomachinery & propulsion). It encourages "training in research through research".

### **INSTRUCTORS AND TOPICS:**

- Ron Bunker, GE Global Research, will address turbine film cooling design, uses, issues, realities, conservatism, limitations, and manufacturing
- Tony Arts, VKI, will address the fundamental physics and basic flow field interaction
- David Bogard, will address the main parameter effects on adiabatic effectiveness and heat transfer / net heat flux; and new geometries
- Sumanta Acharya, will address computational film cooling methods using RANS, URANS, LES, and DNS \*

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