

# GLOBAL

Volume 41: 2001, No.1

# Gas Turbine News

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## Outstanding TURBO EXPO Set for New Orleans

As IGTI/IJPGC/SAM Co-Locate

... *A Look at the Highlights* ...

by Dilip Ballal, IGTI Chair of Conferences



**P**OWER is making news all over the world, and gas turbines are a large and growing part of the international power equation. And not just in the highly visible large land-based power generation market where liberalization and deregulation are giving rise to major systemic changes. Distributed generation is taking on a life of its own, with micro turbines being shipped in quantity to customers to satisfy their own electric power and heating needs. And turbo fuel cell hybrids are receiving greater attention because of their potential for increased efficiency and a decreased environmental impact.

In other market areas, commercial airline travel is expanding while the industry is consolidating and looking for greater engine durability and reliability as well as cost saving repair and maintenance alternatives. And the world's military is being asked to do more with less, having an important impact on research and development, spare parts, and repair and maintenance strategies. Even certain segments of the international maritime community are looking more favorably on gas turbines as their power source of choice.

*As someone for whom up-to-date and technically reliable information about the growing gas turbine market is important to your career and your company's success, you need to be at TURBO EXPO in New Orleans this June 4-7. Here are just a few highlights of what you'll find...*

### Outstanding Technical Congress (June 4-7)

The Technical Congress has always been the life-blood of ASME TURBO EXPO. It is even said that "every significant advancement in gas turbine technology in the last 30 years was first presented at ASME TURBO EXPO." This tradition and world-renowned reputation is kept alive by the more than 1,000 volunteer members of IGTI's 17 technical committees who solicit, organize and in many cases write or review the papers presented.

### Co-Located Events for 2001

This year, for the first time, ASME TURBO EXPO will co-locate with two other ASME events, the International Joint Power Generation Conference (IJPGC) and the ASME Summer Annual Meeting (SAM). IJPGC is an annual power industry event sponsored by the Power, Nuclear, and Fuels & Combustion Technologies Divisions. SAM brings together 300 of ASME's top leaders for its annual business meeting.

### NEWS ON THE WEB

As part of its expanding services, IGTI is now placing current gas turbine industry news highlights on its web site. The news will be updated each week with selected stories. If you have news to submit, please do it by email directed to your editor at: [lindsay@asme.org](mailto:lindsay@asme.org). We hope you enjoy this new service!

*Note: If your web browser is not displaying a recently revised version of our web site, consult with your computer support staff on cleaning out your temporary "cache" files. This may help.*

...continued on page 21



## VIEW FROM THE CHAIR

BOB KIELB, CHAIR, IGTI BOARD OF DIRECTORS



Bob Kielb  
Chair  
IGTI Board of Directors

# TE'01 and "The Mother of All Keynote Sessions!"

**H**ave you marked your calendars on June 4-7 and made your travel plans to attend ASME TURBO EXPO '01 in New Orleans? If not, you should waste no time because Dilip Ballal, IGTI's Chair of Conferences, and his team have put together an outstanding program. It is sure to be of great value for all of us that have an affinity for gas turbines (and/or love the smell of jet fuel in the morning).

Why attend TURBO EXPO? Allan Kidd, IGTI's current Past Chair, eloquently addressed this question in the 2000 - #1 issue of the Global Gas Turbine News. Since I can't improve upon Allan's article, I will summarize his theme with one phrase, Return-On-Investment. That is, nowhere else can you get the high density (spatial and temporal) exposure to buyers, suppliers, competitors, the latest equipment, and the latest technical information. The value of this knowledge to your organization will greatly exceed the investment in your attendance.

New this year is the co-location of TURBO EXPO with the International Joint Power Generation Conference. Attendees will benefit from the synergy of attending two events for the price of one, including not only paper sessions from 17 IGTI committees, but from three other ASME divisions: Power, Fuel & Combustion Technologies and Nuclear. The two expositions under one roof bring together exhibitors from across the globe, and represent not only gas turbine interests, but also the broader electric power community.

The name I suggested for the Keynote Session, "The Mother of All Keynote Sessions", was rejected. Still, it is appropriate. Key leaders from Calpine, GE, International Paper, Siemens Westinghouse, and the U.S. Department of Energy will address the view of buyers and sellers in the power generation

business. Do you think that the subjects of California and deregulation may come up? See this and the previous issue of the Global Gas Turbine News, or visit the IGTI web site, for more information.

This year TURBO EXPO also benefits from the planning efforts of the Distributed Power Generation Task Force, led by Norm Holcombe, Project Manager, DOE National Energy Technology Laboratory. This group of 15 experts from industry, academia, government and the user community have organized a comprehensive treatment of the subject of distributed power generation. This is in keeping with TURBO EXPO's goal of being THE place to hear the latest about the newest. The Distributed Power Generation Task Force's input is expected to expand the presence of fuel cells, micro turbines, and related technology in future IGTI activities.

While attending TURBO EXPO please inquire about IGTI's Technical Committee meetings and activities. For the fourth consecutive year, we experienced an annual 10% growth in the number of participants on the 17 Technical Committees. Currently these committees boast a non-U.S. membership of nearly 30%. In light of the global nature of the use and development of gas turbines, we hope this non-U.S. participation will increase even more in future years.

We are also working hard to increase greatly the number of end-users who participate in IGTI activities. Toward this end Harold Simmons, who has headed up the development of an outstanding Gas Turbine Users Symposium this year, will be hosting an open organizational meeting for a GTUS Advisory Group. Additional details are in this newsletter.

See you in New Orleans. Keep your turbines turning! ☆

“  
*The value of this knowledge to your organization will greatly exceed the investment in your attendance.*  
”



Keynote:  
**Thomas R. Mason**  
Executive Vice President  
Calpine Corporation



Keynote:  
**Del Williamson**  
President  
GE Power Systems  
Global Sales



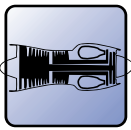
Keynote:  
**Wayne MacIntire**  
Senior Manager  
Power Technology  
International Paper, Inc.



Keynote:  
**Randy Zwirn**  
President and CEO  
Siemens Westinghouse  
Power Corp. and  
Member of the Group  
Managing Board,  
Siemens AG



DOE Perspective:  
**Rita A. Bajura**  
Director  
National Energy  
Technology Laboratory  
U.S. Department  
of Energy



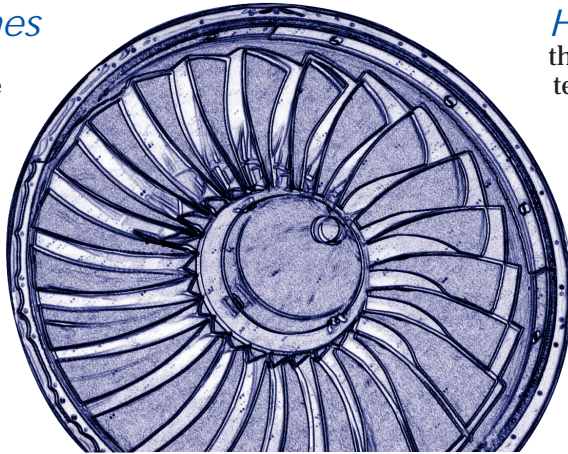
### *Pratt & Whitney Canada Corp.*

(P&WC) marked an important milestone in its 72-year history on November 16, 2000 with the delivery of its 50,000th engine. Beech Aircraft Co. (now Raytheon Aircraft) became the first customer for P&WC's legendary PT6 turboprop engine in 1963 when it selected the engine to power the now famous Beech King Air.

*GE Power Systems'* Greenville, South Carolina facility completed and shipped its largest and most advanced power generation technology, the GE "H" System™, in December 2000. GE Power Systems, GE Aircraft Engines and the GE Corporate Research and Development Center worked together to develop the H technology. The H System gas turbine shipped was intended for the Baglan Energy Plant near Swansea, Wales, UK. Once installed, the H System will supply electricity and heat to industrial and commercial facilities as well as to the Welsh power grid. Fueled by natural gas, the H System will produce 480 MW of electricity, enough to power 168,000 homes.

### *MTU Aero Engines*

has successfully tested a highly-loaded three-stage fan with a pressure ratio in excess of 5:1. Maximum diameter of the fan is 800mm. The fan is an all-blisk (integrally bladed disk) design which incorporates a fiber-reinforced plastic stator stage to save weight and manufacturing costs.



### *Rolls-Royce* and *Snecma Moteurs*

have set up a new joint venture company to conduct programs related to military combat aero engines which are supported by the UK and French governments. Rolls-Royce Snecma Limited will act as prime contractor and single point of contact to the two governments and will be in charge of whole-engine integration studies. All other activities will be sub-contracted.

The *Airbus Military Company* (AMC) has selected the 10,000 - 13,000 shp TP400 engine design to power the planned A400M European transport aircraft. The three-shaft turboprop engine will be jointly developed and manufactured by the six participating companies of FiatAvio (Italy); ITP (Spain); MTU Aero Engines (Germany); Rolls-Royce (UK and Germany); Snecma Moteurs (France) and Techspace Aero (Belgium).

*Rolls-Royce* plc has sold the bulk of its Vickers Turbine Components business to *Royal Bank Private Equity Ltd* (RBPE) for £74 million. Two companies, Ross Catherall Ceramics and Vickers Pressings, will remain with Rolls-Royce. The businesses being sold specialize in precision-engineered products for the automotive, aerospace and industrial gas turbine markets.

*Honeywell's* new 3,000 - 6,000 pound thrust-capable Multi-Purpose Core (MPC) technology demonstrator entered testing in December 2000, meeting all expectations.

The core is comprised of one axial and one centrifugal rotor for the high-pressure section, a reverse-flow, effusion-cooled combustor, and a one-rotor high-pressure turbine section. The MPC has fewer rotors and nearly half as many airfoils as the TFE731.

*Rolls-Royce plc*, one of four partners in the European engine company EUROJET, completed the assembly and test of its first production EJ200 engine for the Eurofighter in December 2000. The other partner companies — FiatAvio of Italy, Spain's ITP and Germany's MTU — have also completed production engines. They will all be delivered early this year to the UK for installation in production Eurofighter aircraft, scheduled to fly later in 2001.

*Capstone Turbine Corporation* shipped its 1,000th micro turbine unit in late 2000. Capstone produced its first two commercial micro turbine systems in December 1998. In 1999, it shipped 211 systems and, through the end of September 2000, had shipped another 548. Capstone's micro turbine is a 30kW unit. ★

*Gas Turbine News in Brief ... is compiled for Global Gas Turbine News  
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# An Autopsy of California's Effort to Deregulate the Electric Utilities (1996-2001)

by Byron Washom  
Spencer Management Associates

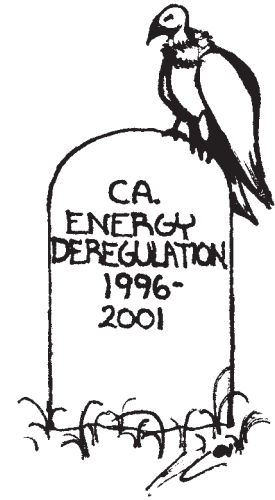
California was one of the first states to legislatively move to deregulate its traditional electric utility monopolies by opening the market to competition among independent power generators in order to give customers a choice of power providers and to drive down retail prices. In January 2001, regulators and politicians declared that the CA deregulation was flawed, had failed and was now dead. While many speculated what to do with the cadaver, what was known was the state's energy crisis had left its two largest investor owned utilities (IOUs), Southern California Edison and Pacific Gas and Electric Co., \$12 billion in debt and unable to buy any more power on credit. The CA Legislature's \$400 million emergency measure to stop the utilities' financial hemorrhaging was exhausted in just 12 days of brokering wholesale energy for the near bankrupt utilities. California's estimated \$10 billion bond sale to finance future power purchases under the state's new emergency rescue package will be the largest municipal issue in history, but it does not address the accumulated debt of the utilities. The next few weeks will witness major events by the courts, legislature, government agencies and creditors that will determine if the utilities seek bankruptcy protection.

During this 1996-2001 period, a number of other states and countries have enacted or contemplated variations to the CA model, but the unpredicted economic trauma on the world's sixth largest economy has rightfully caused serious reexamination of deregulation. While the long-term solutions are conservation, generation and price stabilization, it is becoming apparent that the most significant alteration will be the operating characteristics and sizes of gas turbine generation required in future restructured and deregulated markets.

It is not possible to pinpoint a single cause of death to California's deregulation policy and implementation, but there certainly can be a forensic-like assessment of the fatal flaws.

## Supply of In-State Generation:

1. Electricity consumption in California rose 18% last year alone, more than triple the national average<sup>1</sup>, but it's been a decade since a power plant was built in California. The state has a cumbersome seven-year process for developing new capacity, and CA now imports approximately 25% of its electricity. Sen. Gordon Smith of Oregon complained recently that his state is "in jeopardy of becoming an energy farm to California."
2. California did not establish an effective transition from the regulated to the unregulated market since the energy pricing was tied to a successful recovery of the IOUs' stranded costs rather than the encouragement of significant competition.<sup>2</sup> Two independent audits indicated that the IOUs had paid their parent corporations \$9.5B in dividends in the five years leading up to the electricity



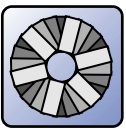
crisis<sup>3</sup> and that the stranded asset recovery was ahead of schedule. There was insufficient competition afterwards as witnessed by the fact that CA currently is at its 28th consecutive day of a Stage 3 Alert, i.e., supply reserves are less than 1.5% of forecasted demand.

3. California's aging transmission grid was designed and built under the generation-transmission-distribution monopoly model and thereby archaic for transmitting greater amounts of marketed electricity to areas with insufficient local generating capacity.
4. IPPs competitively bid for aging in-state generating assets, but some of these assets became unavailable during last year's "super summer peak periods" and this unusually cold, dry winter due to unscheduled maintenance, scheduled major overhaul or repowering.

## Fuel Pricing and Availability:

5. The Independent Power Producers' (IPPs) "dash for gas" in new generating capacity, pipeline capacity constraints and an unseasonably cold winter have caused natural gas prices to quadruple in a year.
6. The financial insolvency of PG&E resulted in the California Public Utility Commission (CPUC) approving a plan on January 31 to keep natural gas flowing to millions of PG&E customers by letting the natural gas suppliers draw directly on the revenues PG&E collects from monthly gas bills from its customers.





### Policy Framework:

7. California set up a highly restrictive power exchange system (CalPX) where most of the power used in the state was bought and sold on day-ahead trading. The IOUs were required to buy their power from CalPX, prohibited from hedging into future markets, and encouraged to sell off the majority of their generating assets. CalPX has now ceased operations.
8. Taking the highest successful bid submitted by wholesalers set the CalPX price. Initially generators kept their bids low to ensure their plants were utilized while knowing they would receive the higher market-clearing price. When demand began to exceed supply, the wholesalers tested the elasticity of demand and found the opportunity for price spikes up to ten fold over the previous year.
9. There was an insufficient supply of contracted "spinning reserve"; therefore, the state's other pooled electricity market, the Independent System Operator (ISO), had to bear even higher prices when tight electricity supplies occurred through unscheduled outages or a shortage of generation capacity. This forced them to buy power on the hourly spot market to prevent blackouts. The largely out-of-state energy wholesalers have exacerbated the crisis by taking advantage of the tight supplies for their own profit.
10. Even though the *wholesale* rates were deregulated, CA instituted a *retail* rate freeze that blocked utilities from passing on higher wholesale costs to their customers. As a consequence, PG&E and SCE accumulated \$12B of debt within a six month period due to the inability to bill customers for inflated wholesale prices.
11. The California-only price "soft cap" exacerbated the state's energy shortage because suppliers stepped up their sales to other Western states willing to pay above the CA price caps, leaving less energy for California.
12. The Federal Energy Regulatory Commission (FERC) declined to impose immediate wholesale price controls, but it did urge the state on Dec. 15, 2000 to sign long-term supply contracts instead of relying on the volatile short-term spot market to buy wholesale electricity.<sup>4</sup> President Bush extended by two weeks, until Feb. 7, directives put in place by the Clinton administration to force power suppliers to continue shipping electricity to California, but Bush made it clear he did so reluctantly and would not (and did not) issue further extensions.

### Market Factors:

13. Once the utilities started to default on their bonds, miss contract payments and threaten bankruptcy, out-of-state power suppliers resisted selling needed electricity to California.<sup>5</sup> Unless forced by the FERC, wholesalers had little incentive to sell power to CA and potentially become unsecured creditors in a bankruptcy. Some wholesalers have filed with the SEC that as much as 25% of their uncollected CA operating income is being held as an accounting reserve.
14. The IPPs had additional incentives to cut back electrical supply to CA during the month of January, 2001 since the value of the natural gas therm was greater than if it were converted into a MWH; thus they sold the natural gas commodity to a credit worthy customer rather than produce and sell the MWH. Then, once they created a shortfall in MWH supply by their production cutbacks, they were able to quickly reenter the electrical supply market and sell limited

quantities of MWH at inflated prices with substantial profits. By agile trading, they were able to sell at the elevated peak of both commodities' markets.<sup>6</sup>

15. Standard & Poor's, Moody's and Fitch lowered the credit ratings on the IOUs, ending any continued and inexpensive debt funding.
16. A hot summer and a cold and dry winter reduced the hydroelectric supply.
17. An academic group released an "Energy Manifesto" which proclaimed that retail rates would need to rise 30-40% to inspire the conservation that would concurrently create market stability and rebuild the financial solvency of the utilities.

### Environmental:

18. There are strict environmental rules that make building plants in CA difficult. President Bush is considering letting the state roll back its air pollution controls for power plants.
19. On December 5, 2000, when operating reserves were forecasted to fall below seven percent, more than 11,000 megawatts of generation remained off line. The majority was categorized as forced outages including a substantial amount of power plant capacity shut down because of expired annual air emission credits. Governor Davis on February 8 used his emergency powers to order a streamlined, 21-day approval process for new power plants and easing emissions controls on older generating units that had exhausted their pollution credits. The Governor is also directing the California Air Resources Board (ARB) to establish a State Emissions Offset Bank to allow facilities to pay mitigation fees to compensate for increased operations. Mitigation fees will be used to maintain state and federal air quality standards by cleaning up facilities and mobile sources that pollute the air, such as older power plants and diesel machinery. This ensures the state's ability to increase generation while maintaining California's commitment to air quality.

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On January 25, 2001, Federal Reserve Chairman Alan Greenspan warned that if the CA energy crisis isn't resolved soon, it could cause a ripple effect throughout the U.S. economy that could undermine the nation's decade-long expansion. "It's scarcely credible that you can have a major economic problem in California which does not feed to the rest of the 49 states." About a third of the states that have not yet opened their power markets to competition are slowing down the process or taking another look at deregulation. So far, twenty-four states and the District of Columbia, which comprise 60 percent of the U.S. population, have moved to deregulate their retail power markets. The PJM (Pennsylvania / New Jersey / Maryland) and Texas deregulation models are now being hailed as the vanguards of deregulation that avoid the weaknesses legislated in CA.

The California failure has been a hard \$12 billion lesson to the utility shareholders, ratepayers and state taxpayers; however, it has strongly defined the operating characteristics needed in the next decade of generating capacity. It is undeniable that there will be a consolidation of the merchant plant players that will have three capabilities: generating capacity, natural gas resources and the ability for instantaneous commodity trading. There is a clear emergence of four highly valued operating characteristics for merchant plant generating assets: a) high variable output performance without significant efficiency penalties, b) fuel type versatility, c) fuel use efficiency, and d) ultra low environmental emissions. The current and future merchant plants built will acquire long term debt based upon the regional fit of the technology, the characteristics described above and the strength of the owner/operator's commodity trading ability. Commercial and industrial companies with demands for highly reliable power will gravitate to distributed generation with smaller gas turbines (and fuel cells in the future) since these companies now are more creditworthy than the IOUs and would therefore have a favorable ability to hedge the future price of their natural gas fuel. This prognosis was further validated on February 8 when Governor Davis expressed his support for legislation that would provide \$20 million for 40 additional megawatts through the retrofitting of natural gas distributed generation owned by municipal water districts. More importantly, he supported the elimination of the standby charges for small renewable and other clean distributed generation.

The California Legislature has authorized \$10B for the state to enter into contracts for as long as 10 years to buy wholesale electricity for about one third of the state's demand at a stable price and sell it to the IOUs. Future legislative efforts contemplate having the state issue revenue bonds to cover the utilities' debts and make their customers pay the money back over a decade through recently approved rate increases of 9 percent for residential customers and 7 – 15% for businesses. The *quid pro quo* may be the state's taking ownership of the two utilities' 26,000-mile network of high voltage transmission lines carrying power to about 24 million of the state's 34 million residents. Regardless of any actions taken by federal or state officials, California and the western U.S. will remain in a perilous energy and economic crisis at least through the summer of 2001, and the reappraisal of restructuring policies will be as intense as the drive to optimize the new individual and mix of generating technologies needed to serve the future markets.

*Byron Washom is a four-time Rockefeller Foundation grantee and a strategic advisor to a number of IPP developers, EPC contractors, energy wholesalers and multi-lateral lenders such as the World Bank and the International Finance Corporation. The analysis contained in this report was prepared as part of the Vision 21 Energy Project at the Advanced Power & Energy Program, UC-Irvine and sponsored by National Energy Technology Laboratory, US DOE. You may comment directly to him at [spencermgt@aol.com](mailto:spencermgt@aol.com). ☆*

### References:

- <sup>1</sup> Energy Information Administration, "California Power Use Soared Above US 2000 Average" Bloomberg News, January 30, 2001.
- <sup>2</sup> Mark Schroeder, a vice president of European government and regulatory affairs at U.S. energy group Enron. Reuters News Service, January 11, 2001.
- <sup>3</sup> Brian Melley, "Audit Confirms PG&E Near Broke", Associated Press, January 31, 2001.
- <sup>4</sup> Curtis Hebert, Chairman of FERC, FERC Commission hearing on January 22, 2001.
- <sup>5</sup> Jim Detmers, CA ISO managing director of operations, January 11, 2001
- <sup>6</sup> San Francisco Chronicle, January 21, 2001.

## CALL FOR PAPERS ... TE'02 AMSTERDAM

**ASME TURBO EXPO – Land, Sea & Air** will be held at the RAI International Exhibition and Congress Centre in Amsterdam, The Netherlands on 3-6 June, 2002. The deadline for submitting abstracts for paper presentations is July 20, 2001. Email [igtiprogram@asme.org](mailto:igtiprogram@asme.org) to receive a Call for Papers announcement. Put "Call for Papers 2002" in the subject line of your email and include your name, email address and complete mailing address.





## Understanding Fatigue

by D.P. DeLuca

United Technologies Pratt & Whitney

In the gas turbine industry, whether it is in the power generation or propulsion sectors, durability is perhaps the most significant attribute a gas turbine can possess. The nature of the tasks performed dictate the impact of premature wear or failure. In the commercial land/sea based arena (power generation, pipeline pumping, land or sea propulsion) the consequences of service interruption are at minimum a loss of revenue. In the commercial aviation sector safety is of paramount concern, while military engines must meet force readiness as well as safety demands.

The repetitive or “cyclic” loading of turbine components associated with generator/pump duty cycles, airline take-off/cruise, or combat mission throttle excursions is a principal source of degradation in turbomachinery. Even manufacturing processes can cause fatigue damage (Figure 1), commonly referred to as “metal fatigue.”

Actually, fatigue degradation is not confined to metals. Most engineering materials (ceramics, composites, aggregates, etc.) are also susceptible to fatigue damage. To understand the nature of fatigue it is first necessary to consider some basic aspects of material behavior.

### Fundamental Material Properties

The strength of a material is a measure of its ability to resist deformation (i.e. being stretched, bent, etc.). Engineers and technicians determine strength by conducting a “tensile” test. In this test a specimen similar to that shown in Figure 2 is employed.

The test is conducted in a tensile test machine (Figure 3). The tensile specimen is pulled apart lengthwise (loaded in axial tension) until fracture occurs. The tensile machine can continuously record incremental values of load and the resultant elongation of the test specimen. A load versus deflection curve is obtained from the tensile test.

From load we can determine stress. From deflection we can determine strain. The tensile strength of a material is illustrated in a stress versus strain curve. Stress is expressed in units of pounds per square inch (psi) and is calculated by dividing pounds of applied load by the specimen’s cross sectional area. Engineering strain is obtained by dividing the change in specimen length by the initial specimen length. The result is expressed as % strain. The results of the test are shown graphically in the stress vs. strain curve (Figure 4) where stress is plotted on the vertical axis and strain is plotted on the horizontal axis.

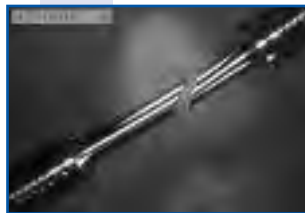
As indicated in Figure 4, there are two distinctly different regions of the stress versus strain curve. In the “elastic” region stress and strain increase linearly up to the proportional limit (P.L.). In this region, removing the load allows the strain to return to zero. Beyond the elastic region we enter the “plastic” region where increases in stress result in disproportionately large increases in strain. Removing the load from the tensile specimen in this region will not result in the strain returning to zero. The specimen is said to be plastically deformed or yielded.

...continued



**Figure 1**

*The airfoil tip and a portion of this turbine blade platform came apart due to high cycle fatigue (HCF) during an ultrasonic cleaning operation. The blade material is a single crystal alloy.*



**Figure 2.**

*This tensile specimen has been tested to rupture. The metal is a “single crystal” turbine blade alloy and has separated along a crystallographic slip plane.*



**Figure 3.**

*A servo hydraulic test machine capable of conducting tensile and fatigue tests, and a variety of other material evaluation tests, including those in aggressive environments.*



### Fatigue

There are three commonly recognized forms of fatigue: high cycle fatigue (HCF), low cycle fatigue (LCF) and thermal mechanical fatigue (TMF).

The principal distinction between HCF and LCF is the region of the stress strain curve where the repetitive application of load (and resultant deformation or strain) is taking place.

HCF is characterized by low amplitude high frequency elastic strains. An example would be an airfoil subjected to repeated bending. One source of this bending occurs as a compressor or turbine blade passes behind a stator vane. When the blade emerges into the gas path it is bent by high velocity gas pressure. Changes in rotor speed change the frequency of blade loading. The excitation will at some point match the blade's resonant frequency causing the amplitude of vibration to increase significantly.

To clarify this concept we need to return to the stress strain curve. When a tuning fork is struck it vibrates at its resonant frequency. As the beams of the fork bend back and forth at hundreds of cycles per second the amplitude of the bending results in strains that are confined to the elastic portion of the stress strain curve. As the vibrations die down and stop the fork returns to its original shape. Only elastic strains have occurred so no permanent deformation has taken place.

The tuning fork can endure tens of millions of cycles under these conditions but eventually it will fail due to HCF. A typical plot of HCF test data is shown in Figure 5. The example of how a turbine, fan or compressor airfoil can become elastically stressed describes one source of HCF excitation.

LCF is the mode of material degradation when plastic strains are induced in an engine component due to the service environment. The results of a typical LCF comparison are shown in Figure 6.

LCF is characterized by high amplitude low frequency plastic strains. If we pull the beams of the tuning fork apart until they are permanently bent we have imparted one half of an LCF cycle. The act of permanently bending means that we have exceeded the elastic limit point on the stress strain curve and have crossed over into the plastic region. Forcing the beams back into the original position will require them to bent or "yielded" thereby completing one LCF cycle. The tuning fork can endure only a very few of these cycles before it will fail due to LCF. In a turbine blade these large strains occur in areas of stress concentration.

Most turbine blades have a variety of features like holes, interior passages, curves and notches. These features raise the local stress level to the point where plastic strains occur. Turbine blades and vanes usually have a configuration at the base referred to as a dove tail or fir tree. This feature is used to attach the blade to the turbine disk. As engine rotational speed increases centrifugal forces result in local plastic strains at the attachment surfaces resulting in LCF damage.

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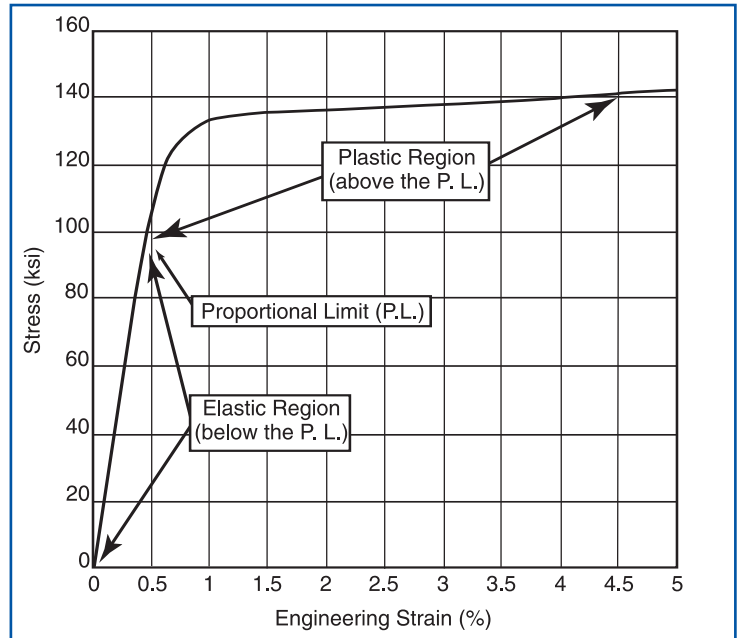


Figure 4.

The stress vs. strain curve for a typical gas turbine alloy. The sample starts to deform plastically at about 100,000 psi and breaks at just over 140,000 psi (140ksi). This curve indicates the strength of the alloy under a static (non-cyclic) load. It would break much sooner (from fatigue) under a vibratory load.

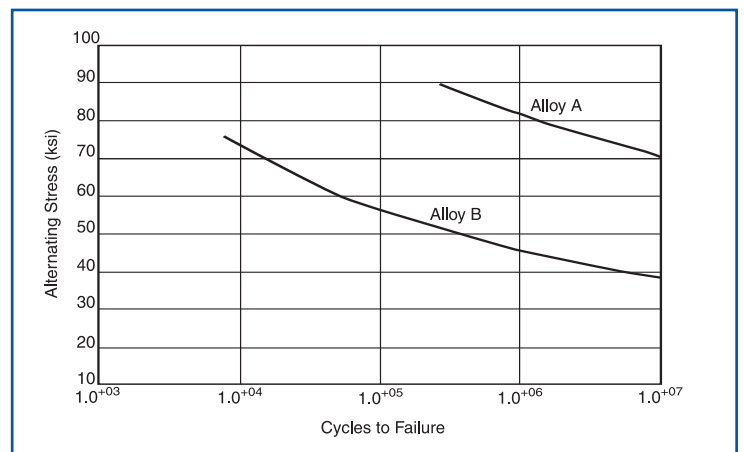
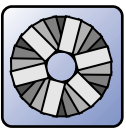


Figure 5.

A typical plot of HCF test data. Alloy A can withstand alternating stresses of up to 70ksi for 10 million cycles (almost forever) without breaking. Alloy B can withstand such stresses for only about 40,000 cycles before failure. For Alloy B not to fail, it would have to be exposed to alternating stresses of less than 40ksi.





### Thermal Mechanical Fatigue (TMF)

So far we have discussed strains that result in a material when it is stressed. In the case of TMF (present in turbine blades, vanes and other hot section components) large temperature changes result in significant thermal expansion and contraction and therefore significant strain excursions. These strains are reinforced or countered by mechanical strains associated with centrifugal loads as engine speed changes. The combination of these events causes material degradation due to TMF.

### How Fatigue Data are Obtained

Engineers and technicians obtain fatigue data much as they do tensile data. The test machines are similar to that shown for tensile tests and similar specimens are used. The chief difference lies in the application of load. In an HCF specimen test, the load is applied to the specimen at 30 to 60 cycles per second and often at much higher frequencies.

In engine components where HCF is a concern, turbomachinery designers observe what is referred to as a material's fatigue strength. This is determined by running multiple specimen tests at a number of different stresses. The objective is to identify the highest stress that will produce a fatigue life beyond ten million cycles. This stress is also known as the material's endurance limit. Gas turbines are designed so that the stresses in engine components do not exceed this value including an additional safety factor.

LCF testing is conducted in a similar fashion, the chief difference being the need for higher (plastic) loading and lower frequencies. As shown earlier, the graphic results appear similar but the lives are much lower and there is no "fatigue strength" per se. Still, components subjected to LCF loading are designed such that stresses remain well below the average lives determined in the LCF tests.

The fatigue life graphs are informative in a number of ways. In addition to determining the maximum stress allowed for a component life to meet ten million cycles, they can also be used to compare the durability of different alloys and show temperature and other environmental effects.

Tensile (stress vs. strain) curves and fatigue (stress vs. life) curves also show us why fatigue is such a concern. If we look at the tensile behavior shown in Figure 4, we can see that the breaking strength is over 140,000 psi. This means that 140,000 lbs. can be hung from a bar with a one square inch cross section indefinitely. If we look at the HCF plot in Figure 5, we can see that the fatigue strength for Alloy B is less than 40,000 psi. This tells us that for infinite life a material's ability to resist a cyclic (vibratory) load is much lower than its ability to resist a sustained load.

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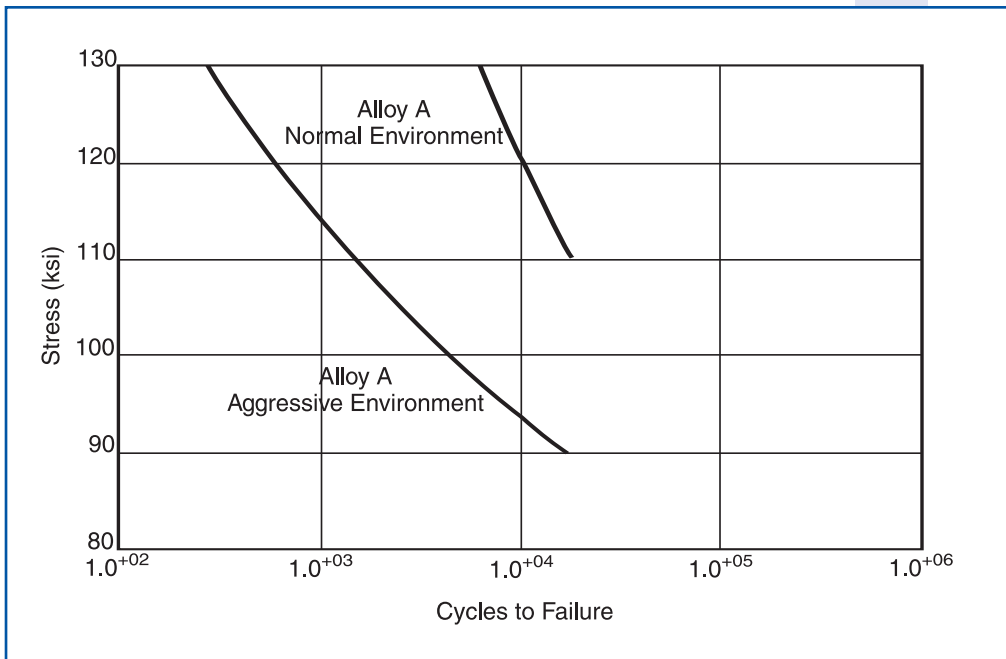


Figure 6.

This LCF data was developed to determine the effects of an aggressive environment (such as extreme heat, cold, etc.) on fatigue life. Fatigue test results in the aggressive environment (left curve) were an order of magnitude lower than the baseline fatigue life tested in air (right curve). For example, in a normal environment, under 120ksi alternating stress, Alloy A would fail at about 10,000 cycles. In an aggressive environment, the same Alloy would fail at about 600 cycles.



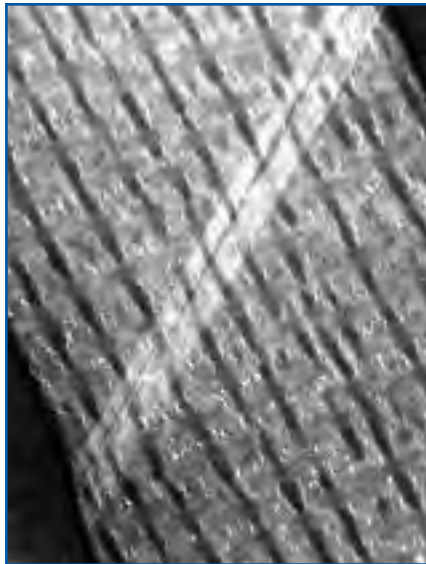
## Fatigue Mechanisms

But how and why do fatigue cracks start? To understand the micromechanics of fatigue crack initiation, we need to know something about metals. Metals are crystalline in nature. Metal crystals are referred to as grains and are composed of uniform layers of atoms stacked one upon another like eggs in a crate. The atoms occupy regular positions in what is called a lattice structure. Atomic forces keep the atoms in place.

When a grain deforms these layers attempt to slide past each other in a shearing process called slip. If the slip displacement is small (confined to the elastic portion of the stress vs. strain curve) the deformation will be reversible. If the slip is large enough (exceeding the P.L.) plastic deformation will occur along the slip plane and the slip will be irreversible. As fatigue cycles accumulate, the number and intensity of the bands increase and the microstructural damage is concentrated (localized) onto a few intense slip bands. The process continues until a persistent slip band (light diagonal band in Figure 7) forms.

Eventually a fatigue crack will form along these slip bands.

The previous discussion is somewhat simplified in that metals are non-homogeneous, containing numerous microscopic discontinuities such as grain boundaries, microscopic pores, carbides and other hard particles generically called defects. These discontinuities inhibit slip and act as local stress concentrators. These features ultimately become fatigue crack initiation sites.



**Figure 7.**

*Multiple slip bands can be seen in this HCF specimen test that was suspended at ten million cycles. An intense slip band has formed (lower left to upper right) and a distinct offset in the gage section (lower left edge of sample) can be seen. The specimen material is a single crystal (a single large grain) turbine blade alloy. The dark lines are primary dendrites, a part of the alloy microstructure.*

## The Importance of Defects

If we look at our stress strain and fatigue curves it would appear that higher alloy strength equates to superior fatigue life. But alloy microstructure can be more important than strength. LCF and HCF cracks frequently initiate at the intrinsic defects previously mentioned. This is not to say that the material is defective. Intrinsic defects can be likened to the knots in knotty pine boards. Defects are a normal feature of an alloy's microstructure. Still, as boards can be selected with fewer knots, alloys can be produced with fewer defects. In the alloy comparison shown in Figure 5, "Alloy A" exhibits clearly superior durability (70ksi vs <40ksi). What is not shown, but is especially interesting, is that Alloy A is significantly lower in strength than "Alloy B." The improvement stems from a low defect content obtained in Alloy A by special heat treatments.

## Summary

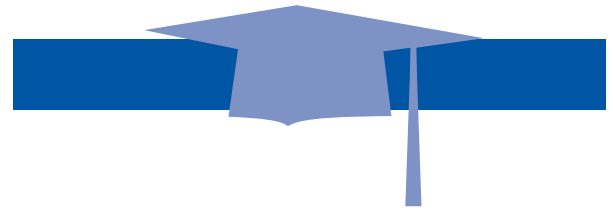
Although this discussion has been directed toward non-engineers, some more advanced issues have been touched upon for the benefit of those readers working in the field. Comparisons drawn between wood and superalloy defect distributions are a simplification, but are useful in conveying a concept.

That being said, for the layman, in a sense, fatigue can be likened to a jackhammer constantly pounding on a concrete sidewalk. A concrete slab can indefinitely support a tremendous constant load; but a relatively small load, applied at a high frequency, can cause failure in a surprisingly short time.

For those non-engineers, and engineers new to this area, it is hoped that you now have a better understanding of fatigue and how fatigue life is determined. For those engineers working in Life Prediction, Materials Behavior, Design and Structures Technology, it is hoped that some of this information has been helpful to you as well.✧



# IGTI Scholarship Awards Top \$900,000



Since initiating its student scholarship program in 1986, the ASME International Gas Turbine Institute has contributed a total of \$903,500 in undergraduate scholarships. Scholarship funds are drawn from revenue generated by IGTI projects, such as the rental of exhibit space at IGTI's annual congress and exposition, and from funds contributed by generous donors like you.\* No ASME membership dues or funds from the ASME general budget are involved. During 2000, IGTI contributed \$20,000 in scholarships.

The 20 colleges and universities receiving the awards and their student recipients for the 2000 program are:

- Alfred State College - **John C. Leck**
- Arizona State University - **Matthew C. LaPaglia**
- Carleton University - **Andrew Cowles**
- Clarkson University - **Leona A. Karnali**
- New Mexico State University - **Jarod Duncan**


- Northeastern University - **Desiree Blais**
- Ohio University - **Anthony Gerstenberger**
- Penn State University - **Corey Paul Raymo**
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- University of Minnesota - **Brett A. Scott / Jonathan P. Robelia** (shared)
- University of Illinois, Urbana-Champaign - **Jeffrey Metzger**
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- Wright State University - **Stephanie M. Puterbaugh**

\* If you wish to contribute to this year's scholarship program, check the box and fill in your gift amount on the form when you register to attend TURBO EXPO 2001. Thank You.

The 2001 IGTI Scholarship Program announcement soliciting applications from qualifying schools will be released in March.★



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## IGTI to Participate in WEC Meeting

The ASME International Gas Turbine Institute is developing plans to sponsor two luncheon seminars in conjunction with the WEC meeting in Buenos Aires next October. Septimus van der Linden of Alstom is serving as IGTI's Chair of South American Conferences, and is coordinating the planned seminars.

In addition, IGTI will have an exhibit in the World Energy Congress Exposition, along with several other ASME departments. The Exposition is part of the overall October 2001 World Energy Congress event which is expected to draw over 5,000 delegates including Ministers and regulators, CEOs and industry operators, senior academic researchers and consultants, representatives from approximately 50 international organizations and financing agencies, and press from all over the world.

Co-located with the WEC Exposition will be the Argentina Oil & Gas Show (AOG), a well-known South American trade show, which this year is called the 18th WEC-AOG 2001. ★



# Combustion Driven Pressure Oscillations (Humming) ... A Low Emission Design Problem

by Stuart A Greenwood, Solar Turbines Incorporated

## BACKGROUND ...

During the last decade the regulatory need for very low emission gas turbines has seen the emergence of combustion driven pressure oscillations (CDPOs) as the major technical problem in the design and development of Dry Low Emissions (DLE) combustion systems. Although there are wide variations in DLE design concepts utilized in gas turbines by various manufacturers, all have experienced this problem.

Pressure fluctuations of small amplitude ( $\pm 0.2\%$  of combustor inlet pressure for example) are always associated with the combustion of fuel in both conventional diffusion flame and Dry Low Emission (DLE) combustion processes due to the inherent unsteadiness of the flame and its heat release. At this level of amplitude, pressure fluctuations are generally not detrimental to achieving the design life goals of the combustion system hardware. Since the production of nitrogen oxides ( $\text{NO}_x$ ) is a strong function of flame temperature, low emission DLE combustion systems are designed to operate at lean (lower) and near uniform fuel-to-air mixture strengths in order to limit the maximum flame temperature level. Any fluctuation in the fuel-to-air mixture strength has a greater effect on the heat release rate when the overall mixture strength is lean, as in a DLE system, than when the mixture strength is rich (and near stoichiometric) as in a conventional diffusion flame system. This makes DLE systems much more prone to developing pressure fluctuations since the variation in heat release rate is the driving force for these oscillations. If conditions exist which cause these oscillations to become unstable, large fluctuations in pressure can occur. The term combustion driven pressure oscillations, or CDPOs, is used here to denote oscillations that become unstable and cause unacceptably large amplitude pressure fluctuations.

CDPOs produce large fluctuations in the combustion pressure. Amplitudes of  $\pm 3\%$  of the combustor inlet pressure, or greater, are not uncommon. The physical damage that CDPOs cause include heavy fretting between combustor mating parts, high cycle fatigue cracking of the combustor components and bearing distress in the engine rotating assembly... depending on the magnitude of the pressure amplitude. CDPOs can also contribute to flame flashbacks into the premixing chamber that can melt the metal walls. These oscillations are within the audible range with frequencies from 150 to 1000 Hz, and are often described as a "humming" or "singing" tone. In contrast to "combustion rumble", which generally occurs at frequencies below 100 Hz and sounds and/or feels destructive to the engine operator, CDPOs may not seem particularly harmful, but often are.

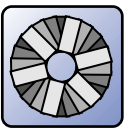
Much to the annoyance of the customer, CDPO problems may be encountered in the field on engines which have been set up to operate without oscillations (or with oscillations of very low amplitudes) during the engine factory acceptance test. In most cases this is because of the differences in surrounding (ambient) conditions or changes in fuel composition at the customer's site. These changes, for any given engine power setting, affect the rate of combustion reaction. Even a fully

proven gas turbine can encounter CDPO problems when up-rated to operate at a higher turbine inlet gas temperature because this generally means the combustion system operating conditions are altered. In such cases a seemingly innocuous change to the DLE combustion system, for example changing the air distribution to maintain a constant flame temperature to prevent increased  $\text{NO}_x$  emissions, can bring on CDPO problems where none existed before.

## THE CAUSES ...

Whenever a flame is in an enclosed chamber the potential for CDPOs exists. Lord Rayleigh in 1878 explained the underlying mechanism, thereafter known as the Rayleigh Criterion. As applied to this problem, the Criterion indicates that heat release drives pressure fluctuations if it increases at the moment when the oscillating pressure is highest, or decreases at the moment when the pressure is lowest. If the heat release variation is out of phase with the pressure fluctuations, then it has a dampening effect on the pressure fluctuations. If it is in phase, magnified fluctuations occur. (The situation is analogous to a child playing with the water in a bathtub. If he moves his hand in a direction opposite to the established wave motion, he dampens the waves. If he moves his hand in phase with the wave motion, he gets water all over the floor!) In this more sophisticated case, instability occurs when the magnitude of the driving force (resulting from the interaction between the unsteady heat release and the acoustic pressure and velocity fluctuations) is greater than the inherent acoustic dampening of the combustion system. The system becomes unstable and resonates and the pressure amplitude can become unacceptably high, producing CDPOs. DLE combustion chambers tend to have less acoustic dampening than conventional chambers because (due to emission concerns) they generally have solid

...continued



Analysis of the acoustic properties of a combustion system can be quite complex. Several modes of acoustic oscillation or a combination of modes can occur. The acoustic properties of the combustor walls and the boundary conditions at the inlet and exit of the combustion system play a significant role in any analysis. Typical oscillation modes are: axial, along the length of the combustor; circumferential, around the interior of the combustor; and radial, from the center to the periphery of the combustor. Some of the observed frequencies are so low that they cannot be associated with physical characteristics of the combustor. In this case a bulk mode, similar to that in a Helmholtz resonator, may be evident. The acoustic properties of the flame itself and/or the impedance of the injector are difficult to determine analytically. Whereas the possible modes may be definable by analysis, determining whether a mode will be unstable, leading to CDPOs, can be beyond the ability of analytical techniques.

flame tube walls. Conventional combustion chambers have various hole patterns in the flame tube walls to admit air for wall cooling, or to reduce the temperature of the hot gases entering the turbine section.

The Rayleigh Criterion, however, is of little practical value because it does not provide sufficient information to determine whether or not instability will occur in a given combustion system design under given aero/thermodynamic conditions. Aerodynamic flow turbulence and instabilities, in vortex shedding for example, influence the rate of fuel consumption in the flame. As a consequence, variations in the rate of heat release occur which lead to fluctuations in pressure. These aerodynamic instabilities tend to produce a broad frequency band noise level. However, if these instabilities couple to the acoustic characteristics of the combustion system, then the effect is amplified, leading to high amplitude fluctuations in pressure. Unlike conventional diffusion flame combustors where fuel is injected directly into the flame zone, DLE combustion systems contain chambers for premixing the air and fuel before the mixture is delivered to the flame zone. Because the mixture is compressible, and created by low pressure differentials, a variation in mixture strength can occur. Variations in mixture strength over time, caused by pressure fluctuations, influence the heat release rate when the resultant rich or lean "pockets" reach the flame zone. The timely arrival in the DLE reaction zone of "pockets" of rich or lean mixture affect the heat release rate throughout a large portion of the entire reaction zone. In a conventional combustor, where wide variations in mixture strength exist, only a small amount of the fuel burns as a lean mixture similar to that of a DLE system. Hence, variations in the mixture strength do not affect the whole reaction zone to the same extent.

### SOLUTIONS ...

In most DLE combustion systems a pilot fuel injector, which may or may not be integral with the main premixing fuel injector, is used to extend the operating range of the combustor to avoid flame-out when the engine undergoes load transients and to assist in starting, accelerating and low load operation. The pilot injector produces a small diffusion flame, similar to the flame in a conventional combustor, within the body of the main premixed flame. This has the effect of stabilizing the premix flame. Increasing the amount of the pilot fuel flow will dampen out CDPOs. Adjustment of the pilot fuel schedule for different engine loads is therefore one means of preventing CDPOs. This method of CDPO control, while being generally effective, sometimes has the opposite effect and promotes CDPOs. The reasons for this are not well understood. Because the pilot creates a diffusion flame, this leads to an increase in NO<sub>x</sub> emissions. In some cases, the combustion system can then no longer meet the required emission levels. Variations on this theme are used ... such as deliberately creating a non-uniformity in the fuel/air mixing in the premixer. There is evidence to indicate that the achievement of very uniform premix conditions, which one may consider beneficial to the goal of achieving low emissions, might actually be counter productive and lead to worsening CDPO problems.

In order to suppress CDPOs directly, it is necessary to prevent coupling between the combustion system acoustics and the heat release. Both active and passive methods have been demonstrated. In an active system the total fuel flow rate, or a portion of it, can be pulsed with a fast acting valve or valves so the time of arrival of rich and lean "packages" of fuel/air mixtures at the flame front can be altered to be out of phase with the oscillations thereby suppressing them. For this system to be successful dynamic pressure transducers have to be mounted on the combustion system to detect the frequency and phase of the oscillations. This information is processed in real time and control algorithms are developed to modulate the fast acting valves to achieve the desired phase relationship. Siemens AG has reported successful incorporation of an active system of this type on a production gas turbine. In this case the pilot fuel was pulsed because, as mentioned previously, the pilot flame has a large effect on the premix flame.

...continued





### SOLUTIONS ... (continued)

One passive system that the author is familiar with was conceived by Geo Richards at the Federal Energy Technology Center. Mr. Richards has worked closely with the Combustion Engineering Dept. of Solar Turbines Incorporated on the mechanisms causing CDPOs. He has developed a simple time lag approach, known as the Tau-f Criterion, which is illustrated in Figure 1. The pressure fluctuations,  $P(t)$ , compress the air flow and the resultant velocity fluctuations,  $U(t)$ , are 180 degrees out of phase with the pressure. If it is assumed that the fuel flow rate is not affected by the pressure oscillations, then the velocity fluctuations cause the production of rich and lean fuel/air ratio "pockets" inside the premixer which travel downstream to the flame front.

In a real combustion system the fuel flow rate is probably significantly affected by the pressure oscillations, but this doesn't invalidate the Criterion. In Figure 2, the time lag  $\tau$  is estimated as the distance between the point of fuel injection and flame front divided by the average axial velocity of the premixed fuel/air mixture. The distance is made up of two components, the length of the premix section,  $L$ , which is known, and the distance from the end of the premix passage to the flame front,  $L''$ , which typically is not known. When a rich pocket arrives at the flame front it will result in an increase in heat release, and if this coincides with a pressure fluctuation peak, then CDPOs will most likely occur. Referring to Figure 1, this occurs when the time lag ( $\tau$ ), which equals  $t_2 - t_1$ , is an integer multiple of the acoustic period. Because the acoustic period is the reciprocal of the acoustic frequency,  $f$ , the Criterion can be stated as:

$$\text{Tau-f Criterion: Time lag } (\tau) \times \text{acoustic frequency } (f) = 1, 2, 3 \dots \text{ etc.}$$

In practice, it is not necessary that the heat release be exactly in-phase with the pressure peak. Some driving will occur from heat release fluctuations that either lead or lag the pressure as much as 1/4 of the acoustic period. The Criterion is really a re-statement of the Rayleigh Criterion in a way that can be applied by a combustion engineer. Like the Rayleigh Criterion it does not provide information on whether or not instabilities will occur, but can be used to suppress a CDPO problem that has been encountered. For instance, by moving the point of the fuel injection (i.e. changing the distance  $L$ , by 1/4 of the acoustic period) there is a good probability that the instability will be suppressed. Of course the simplifying assumptions ... that a positive pressure causes an immediate reduction in air flow, that the arrival of a rich mixture pocket provides an immediate increase in heat release, and that the fuel flow rate does not change due to the pressure change ... do not take into account the acoustic impedances in the system or the complications associated with heat release in a flame. Nevertheless, the application of the Criterion has been found to be successful in solving CDPO problems and in analyzing combustion test rig results for experiments conducted over a wide range of engine conditions.

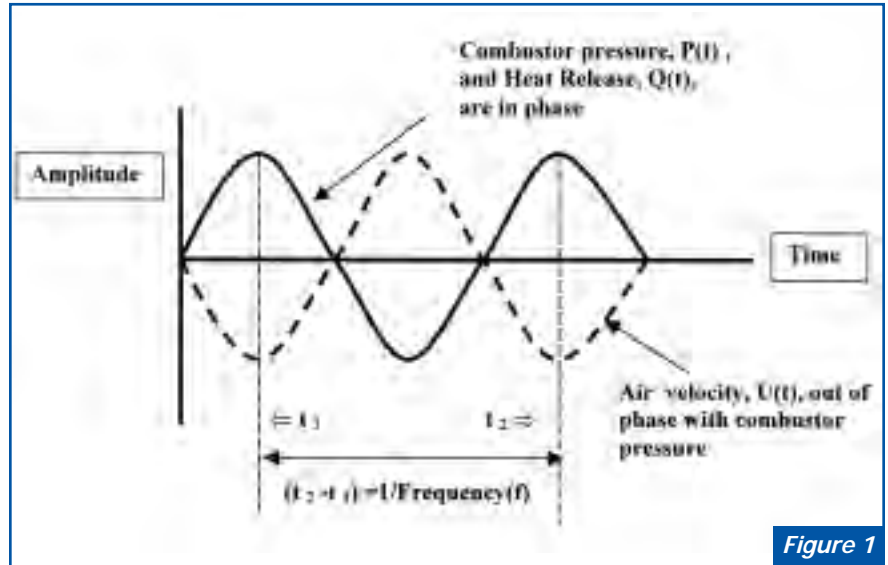


Figure 1

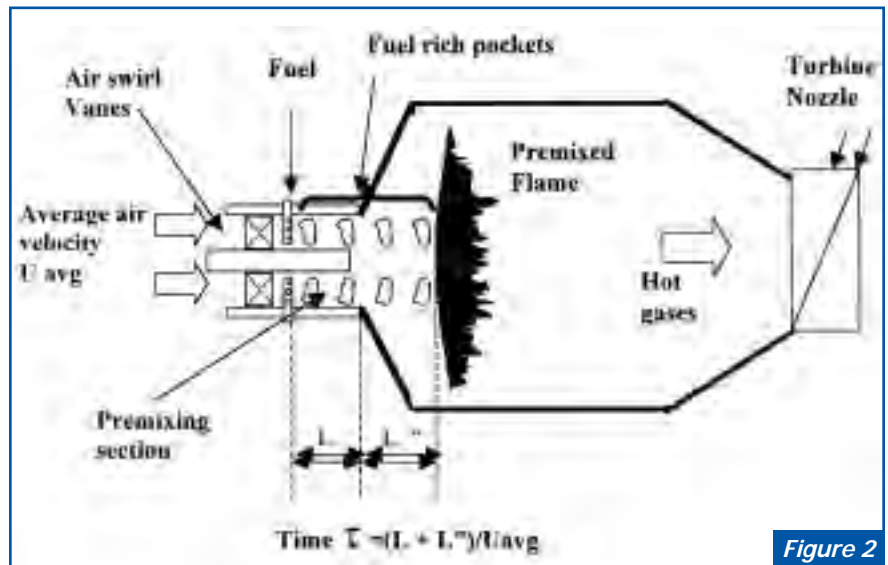
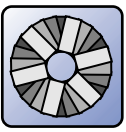


Figure 2





## CONCLUSION ...

At the present time an all-embracing design methodology does not exist so that a combustion engineer can confidently design a combustion system which will be free of CDPOs. The solution to CDPOs is arrived at by a combination of theoretical analysis and experimental verification of the proposed solution. The same theoretical approach may work for one combustion system and not for another of similar design. However, with the effort that has been put into the problem to-date, combustion engineers are developing a growing understanding of the CDPO characteristics of the combustion systems for which they are responsible. As a better understanding of the problem is achieved, it is hoped that a universal analytical treatment will evolve that is applicable to all combustion systems. This will enable a valid analysis to be performed during the combustion system design phase. ★

*NOTE: In recent years the subject of CDPOs has received ever-increasing attention by numerous investigators and writers, both from a theoretical and a practical viewpoint. At least three presentations on this important topic will be available to congress registrants at TURBO EXPO '01 in New Orleans this June.*

## Bibliography and Acknowledgements:

In writing this article the author has consulted several papers presented on CDPOs. These are listed below and the contributions made by their authors are acknowledged. The author would also like to thank his colleague, Mr. V. Mohan Sood, for his assistance in the preparation of this article.

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3. Characterization of Oscillations During Premix Gas Turbine Combustion ... Richards and Janus; FETC, Morgantown, WV [ASME 97-GT-244](#)
4. Investigation of the Thermoacoustic Characteristics of a Lean Premixed Gas Turbine Burner ... Paschereit and Polifke; ABB Corporate Research Ltd., Switzerland [ASME 98-GT-582](#)
5. Theoretical Investigation of Combustion Instability Mechanisms in Lean Premixed Gas Turbines... Lieuwen and Zinn; Georgia Institute of Technology [AIAA 98-0641](#)
6. Combustion System Damping Augmentation with Helmholtz Resonators ... Gyaling, Copeland, McCormick and Proscia; UTRC [ASME 99-GT-268](#)
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8. Industrial Trent Combustor- Combustion Noise Characteristics ... Scarinci and Halpin; Rolls-Royce Canada [ASME 99-GT-9](#)
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10. Industrial RB211 DLE Gas Turbine Combustion Update ... Willis and Moran; Rolls-Royce plc, UK [ASME 2000-GT-109](#)
11. Suppression of Dynamic Combustion Instabilities by Passive and Active Means ... Berenbrink and Hoffmann; Siemens AG, KWU, Germany [ASME 2000-GT-79](#)

## IGTI Congratulates New ASME Fellows

The Board of Governors of ASME International has elected 47 ASME members with gas turbine interests to the grade of ASME Fellow since the *Global Gas Turbine News'* last listing. **Fellow grade is the highest elected grade of ASME membership, the attainment of which recognizes exceptional engineering achievements and contributions to the engineering profession.**

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# Gas Turbine Users Symposium to Focus on User Needs

by Harold Simmons, P.E., Southwest Research Institute, GTUS Program Chair

Users of gas turbine engines, be they owners, operators, engineers, technicians, managers, or repair and maintenance personnel, should attend the Gas Turbine Users Symposium (as part of ASME TURBO EXPO 2001 in New Orleans) for three reasons:

1. To improve the profitability of gas turbine operation and ownership with the latest technology and practices;
2. To enhance individual career performance and personal achievement; and
3. To develop networks among industry cohorts and acquire technology to solve current and future problems.

## IMPROVE PROFITABILITY

The specific interests of GTUS attendees who operate gas turbines in electrical power generation, oil and gas transmission, and industrial applications are accommodated with three different focused tracks.

- Business and Economic Strategies
- Performance Enhancement and Preservation
- Hot Section Repair and Integrity

The seven or more sessions in each track include panel discussions on the latest strategies for improving operations, tutorials for basic and advanced training, and discussion groups to encourage user-to-user dialog.

The Business and Economic Strategies track includes sessions that range from financing costs to LTSAs, maintenance strategies, turbine upgrades, regulatory issues, and the technology advances of future turbine systems.

The Performance Enhancement track addresses performance testing, new techniques in condition monitoring, mitigation of compressor fouling, inlet fogging, an introduction to gas turbines and applications, principals of regulatory development, and procurement procedures to ensure increased reliability and performance.

The Hot Section Repair and Integrity track covers diagnosing gas turbine failures, assessing the remaining hot section life, coatings for both turbine and compressor sections, and the advantages of advanced component repair techniques.

GTUS attendees may follow the established track most suited to their interests, or may mix and match sessions from all GTUS tracks to create a personalized learning itinerary.

## ENHANCE CAREER PERFORMANCE

Six tutorials will be presented to help you learn how to apply gas turbine technology to improve plant profitability.

- Practical Aspects of Cogeneration & Combined Cycles
- Gas Turbine Combustion and Emissions
- Gas Turbine Materials for the Non-Metallurgist
- GT Maintenance and Refurbishment
- Gas Turbine Failure Root Cause Diagnosis
- Maintenance Strategies to Minimize Life Cycle Costs

The tutorial sessions cover a wide range of gas turbine technology. An overview of Cogeneration & Combined Cycles provides rules of thumb and modern optimization methods for gas turbines and HRSGs. The science of combustion is the basis for a tutorial on the various ways to mitigate environmental emissions. Metallurgical examination, mechanical testing, and interpretation of results are the core technologies taught in a session on root cause failure diagnosis. Experts present a basic course on the Application of Superalloys and High Temperature Coatings in Gas Turbines, how they degrade in

service, and life prediction methods. The maintenance and cost impact of differences between earlier and newer technology components are reviewed in GT Maintenance and Refurbishment. The tutorial on Maintenance Strategies to Minimize Life Cycle Costs conveys the basic methodology and data used to compute cost functions such as NPV and the application to a real world installation.



The GTUS is an ideal event for personal advancement or for supervisors to reward a blossoming young engineer with career building training taught by recognized industry experts.

...continued on page 20

# One Segment of TE'01 to Focus on Land-Based Power Generation

by Abbie Layne, U. S. Department of Energy, TE'01 Technical Congress Program Chair

The theme for TURBO EXPO 2001 is "New Horizons for Global Power." This theme will run through the Keynote Session as well as the Technical Congress program and will emphasize research and development needs and trends to serve the long-term market for gas turbine products in all their applications ... land, sea and air. The Technical Congress will have

140 paper and panel sessions presented over a four-day period. These sessions will cover all aspects of gas turbine design, development and performance including many outstanding sessions relating to basic design as well

as aircraft, marine, vehicular, pipeline and land-based power applications. For convenience, the 50 sessions dealing with land-based power generation will be organized into 8 Power Tracks. These Tracks are announced in the current Advance Program and will be clearly detailed in the Final Program.

Power Tracks are focused in the areas of: Coal, Biomass & Alternative Fuels; Combustion; Cycle Innovations; Electric Power; Industrial Cogeneration; Operating Concerns; Materials; and the "Hot Topic" area of Distributed Power. Some of the important topics covered include: coal utilization and gasification, IGCCs, sources and controls of combustion instabilities, novel cycles, advanced gas

turbines, new developments and enhancements for cogeneration and combined cycle applications, regulatory issues, emissions, failure diagnosis, materials, coatings, repair strategies, and integrity and durability issues.

Distributed power is projected to serve up to 40% of new electric power generation needs worldwide over the next decade. Distributed power is

modular electric generation or storage located near the point of use. Distributed power technologies provide site-specific benefits to end-use customers and electric utilities, such as high power

quality, improved reliability and low-cost power delivery. The Distributed Power Track is organized by the IGTI Task Force on Distributed Power Generation and contains seven sessions. These sessions cover micro turbines, turbo fuel cell hybrids, fuel cells, electric and interconnect issues, and user's viewpoints of the market and applications of distributed power.

Register today for this important Technical Congress. And remember, with this registration you can attend the Gas Turbine Users Symposium sessions as well as the sessions of the co-located IJPGC conference. We'll see you in New Orleans! ✧



## Gas Turbines to Help Satisfy a Power Hungry U.S.!

Gas turbine power plants are expected to provide up to 80 percent of the new electric capacity for the U.S. over the next 20 years. These plants will need to be clean and also provide reliable, available power under the emerging deregulated electricity markets. Population growth, a booming economy and the voracious use of electricity by the Internet are straining our nation's power infrastructure. Power shortages have occurred across the U.S. and they can only be prevented in the future by the addition of new, modern power plants. To address this national need for additional power, the competitive electricity market will need power systems that can utilize a variety of fuels, operate reliably, be available to supply rapid demands for power, and be environmentally friendly. Gas turbines are anticipated to fulfill this need for both distributed and central power applications. As the adjacent article explains, this is but one of the many applications of gas turbine technology available to participants at TURBO EXPO 2001 this June.

## Y2K on Display at TURBO EXPO

### ASME TURBO EXPO 2001 Leadership Team

**Executive Conference Chair:**

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 Entergy Wholesale Operations

**IGTI Chair of Conferences:**

**Dilip R. Ballal**, Hans von Ohain  
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**Ron Natole**, President, Natole Turbine Enterprises, Inc.

**Technical Congress Program Chair:**

**Abbie Layne**, Product Manager, U.S.  
 DOE / NETL

**Gas Turbine Users Symposium Chair:**

**Harold Simmons**, Principal Engineer,  
 Southwest Research Institute

**Local Liaison Committee Chair:**

**Matt Greek**, General Manager,  
 SW Region, Reliant Energy

**O**f special interest in the exhibit hall this year will be an unusual display of a gas turbine powered motorcycle. Ted McIntyre, inventor of the Y2K turbine powered 320-plus hp 266 mph street bike, will have it on display at TURBO EXPO. Four bikes have been produced by Marine Turbine Technologies, LLC. Jay Leno, host of the Tonight Show, owns serial #2. In an interview with Cycle World Magazine, Leno said, "At idle, it's making 10 horsepower. Once you're rolling though, it's like the hand of God pushing you in the back. It's frightening." Even with the Y2K's frightening power, Leno still says he's glad he bought it. ✪



For the Technical Congress  
 this year ...

Both individual  
 Pamphlets and the very  
 popular CD (containing  
 all TE'01 papers) will be  
 available for sale in the  
 ASME Paper Sales area.

### How to Register:

To register for the Technical Congress, the Gas Turbine Users Symposium or as a Complimentary Visitor to the Exposition: VISIT THE IGTI WEB SITE AT: [www.asme.org/igti](http://www.asme.org/igti). For questions email: [igtiregistration@asme.org](mailto:igtiregistration@asme.org) or phone: (404) 847-0072, ext. 229.

### Hotel Reservations:

This year IGTI is fortunate to have all of its rooms at the Hilton New Orleans Riverside Hotel, the Headquarters for TE'01 and adjacent to the convention center. Book online through the IGTI web site at: [www.asme.org/igti](http://www.asme.org/igti). The events/te2001 page links directly to the hotel web site.

### Delta is the Official Airline for TE'01:

Call Delta Meeting Network Reservations at 1-800-241-6760 or your local Delta agent. IMPORTANT: Refer to File Number: 175559A for U.S. flights, or 175560A for flights originating outside the U.S.

### Participating Organizations:

World Energy Council  
 (WEC)  
 Gulf Coast Power Association  
 (GCPA)  
 ASME Gas Turbine Technical Chapter,  
 Houston  
 Japan Society of Mechanical Engineers  
 (JSME)

### Supporting Publications:

Diesel & Gas Turbine Publications  
 Forecast International / DMS  
 Freund Publishing House, Ltd.  
 Gas Turbine World  
 Gas Turbo Technology  
 Mechanical Engineering  
 Modern Power Systems  
 Power Plant Technology  
 Turbomachinery International  
 World Cogeneration

### Sponsors of Shared Activities at the New Orleans Event:

Alstom Power, Rugby, UK  
 Bently Nevada Corporation  
 Entergy Wholesale Operations  
 Hilliard Corporation, The  
 National Electric Coil (NEC)  
 Parker-Gas Turbine Fuel Systems  
 Thermal Paint Temperature  
 Technology (TPTT)  
 Turbo Care / Demag Delaval Services

(as of 3/1/01)

## Other Activities

Other activities taking place in conjunction with ASME TURBO EXPO include:

- ... **Non-ASME Short Courses** (Separate registrations required):
  - Cranfield University (3 day course; May 31-June 2) "The Performance and Operational Characteristics of Gas Turbine Engines." Info.: Mary Howard, phone: ++44 (0) 1234-754644 in the UK; or [www.cranfield.ac.uk/sme/pep/tp/cpd.htm](http://www.cranfield.ac.uk/sme/pep/tp/cpd.htm)
  - The Boyce Consultancy (2 day course; June 1-2) "Basics of Gas Turbine Technology: A Practical Course for Plant Engineers." Info.: [www.boyceconsultancy.com](http://www.boyceconsultancy.com) or Phone: (713) 807-0888 in Houston, TX.
- ... **Guest Tours:** Six tours available at different times during the week ... City Tour 6/3, 6/4; Uptown on the Avenue 6/4; Mardi Gras Madness 6/5; Faith and Folklore 6/5; Laura and Oak Alley Plantations 6/6; and Now You're Cookin'! 6/7. (Separate registrations required.) Info.: ASME Info Central in NJ. Phone: 1-800-843-2763 or on-site if space available.
- ... **Hosted Welcome Reception**, Sunday, June 3; 7:00-8:30 pm. (Jointly with IJPGC and SAM.) Badge required for admittance.
- ... **Hospitality Room:** June 4-7; 7:30 am-5:00 pm, at the Hilton Riverside Hotel.
- ... **Exposition Grand Opening Ribbon Cutting:** Monday, June 4; 11:30 am.
- ... **IGTI Scholar Award Presentation:** "Convective Heat Transfer and Aerodynamics in Axial Flow Turbines" by Michael Dunn; Monday, June 4; 1:00-1:45 pm. Technical Congress and IJPGC registrants only. Badge required.
- ... **Awards Banquet:** Monday, June 4; 7:30-10:00 pm. (Jointly with IJPGC.) (Ticket required.)
- ... **Organizational Meeting for the GTUS Advisory Group:** Date and location to be decided. Updates on IGTI web site. Info.: Harold Simmons in San Antonio, TX (210) 522-2557.
- ... **Organizational Meeting for ASME Louisiana Gas Turbine Chapter:** Time and location to be decided. Info.: Prof. Sumanta Acharya, LSU; phone: (225) 388-5809 or Prof. Ting Wang, UNO; phone: (504) 280-7183.
- ... **ASME President's Dinner:** Wednesday, June 6; starts at 6:30 pm. (Ticket required.) Info.: ASME Info Central in NJ. Phone: 1-800-843-2763 or on-site if space available.
- ... **Meeting of the World Energy Council's Performance of Generating Plant Committee:** Thursday, June 7; all day. Location to be decided. Info.: Bob Richwine, Atlanta, GA. Phone: (678) 579-6982.
- ... **Propulsion & Power Systems Alliance Workshop #6:** (DOD/DOE/NASA/Industry) Thursday, June 7; hosted by the IGTI Marine Committee. Info.: Ron Colantonio, NASA Glenn Research Center (216) 433-6370.
- ... **Facility Tour:** NASA Stennis (Propulsion Testing Center): Thursday, June 7; 1:15-6:30 pm. (Register June 4-6 at NASA Booth in the Exposition.)

### Special Thanks ...

...to Professor Sumanta Acharya of Louisiana State University, and Professor Ting Wang of the University of New Orleans, who are arranging for TURBO EXPO Session Assistants.

## Awards Banquet

The following persons will be among the award winners honored at the Joint IGTI/IJPGC Awards Banquet on Monday, June 4 at the New Orleans Hilton Riverside Hotel. Tickets are available for purchase by contacting Laura Kemp at the IGTI office in Atlanta. E-mail: [kempl@asme.org](mailto:kempl@asme.org)

### 2001 R. Tom Sawyer Award:

Max Bentele

### 1999 ASME Gas Turbine Award:

Luke H. Cowell, Robert C. Steele, Steven M. Cannon and Clifford E. Smith for their paper entitled, "Passive Control of Combustion Instability in Lean Premixed Combustors."

### 2001 IGTI Scholar Award:

Michael Dunn, "Convective Heat Transfer and Aerodynamics in Axial Flow Turbines."

### 2001 Aircraft Engine Technology Award

John Adamczyk

### 1999 John P. Davis Award:

Christopher Freeman and Arthur L. Rowe for their paper entitled, "Intake Engine Interactions of a Modern Large Turbofan Engine."

### ASME Dedicated Service Award:

Walter F. O'Brien

## Registration Hours:

Sunday, June 3 . . . . . 2:00pm – 4:30pm  
 Monday, June 4 . . . . . 8:00am – 5:30pm  
 Tuesday, June 5 . . . . . 8:00am – 5:30pm  
 Wednesday, June 6 . . . . . 8:00am – 5:30pm  
 Thursday, June 7 . . . . . 8:00am – 12:30pm

## Exposition Hours:

Monday, June 4 . . 11:30am (*Ribbon Cutting*)  
 . . . . . 11:45am – 2:00pm  
 . . . . . 4:30pm – 6:00pm  
 Tuesday, June 5 . . . . . 9:00am – 6:00pm  
 Wednesday, June 6 . . . . . 9:00am – 6:00pm  
 Thursday, June 7 . . . . . Exposition Closed

## Session Hours:

Mon. - Thur. . . . 9:00am - 4:30 or 5:00pm

## Von Ohain & Whittle to Open Exposition!

The 3-day world-class Exposition of gas turbine and power industry technologies at the Ernest Morial Convention Center in New Orleans will begin Monday, June 4, at 11:30 am with the Grand Opening Ribbon Cutting Ceremony. The co-inventors of the aircraft gas turbine engine were Sir Frank Whittle in England and Hans von Ohain in Germany. Those great men are no longer with us, but ASME is honored to have Mrs. Hanni von Ohain, wife of Hans von Ohain, and Ian Whittle, son of Sir Frank Whittle, present in New Orleans to open the Exposition. Time allowing, one or both will be available to sign copies of *The History of Aircraft Gas Turbine Engine Technology in the United States ... A Tradition of Excellence* by James St. Peter, available for purchase at the show. ✧

## International Experts to Discuss History and Future Trends in Gas Turbine Technology

Dr. Erik Prisell, Chief Engineer of Aero Propulsion Systems in the Defense Materiel Administration, Stockholm, Sweden will chair a panel of international experts who will discuss lessons learned from past developments and emerging future trends for this remarkable and versatile power plant. Mrs. Hanni von Ohain and Ian Whittle will be honored guests at the panel discussion. ✧

## Panel to Discuss Advanced Gas Turbine Cycles for Marine Applications

Diesel engines have long dominated the maritime sector as the power plant of choice. But now, rising environmental concerns and recognition of superior features have led many commercial ship designers to re-examine and select gas turbines as the power plant of choice for many applications. The Achilles' Heel of gas turbines is still part load fuel economy. However, progress is being made in eliminating this liability. A distinguished panel will discuss innovative gas turbine cycles, turbo fuel cell hybrids, nuclear closed cycles, and much more. ✧

## Gas Turbine Users Symposium

... Continued from page 16

### DEVELOP NETWORKS

A practical approach to solving gas turbine operating problems is part of a network where experiences in problem solutions can be shared. Opportunities to interface with other users provide the seeds for developing these economically advantageous networks. A strong attraction for operators will be GTUS panel sessions and discussion groups that provide open forum discussions on problems where similar interests can surface. The specific GTUS tracks make it possible to narrow the focus and to maximize contacts with operators of similar equipment. Additional contact opportunities include the GTUS Advisory Group organizational meeting, a GTUS leadership meeting, the Exposition and various social activities. More about the formation of the GTUS Advisory Group appears in a separate article in this newsletter.

The Exposition at TURBO EXPO '01 is the primary venue for participant networking with OEMs and service providers. The OEMs and service providers need to meet their customers, and the greater the participation and influence of gas turbine users at TURBO EXPO, the greater the number of OEMs that will exhibit and be available for user interface.

### CONCLUSION

IGTI strives to be the premiere organization for the exchange of gas turbine information in the world; this includes information that is useful to users of gas turbines as well as to designers and manufacturers. A concerted effort is in place to make the Gas Turbine Users Symposium a forum where users can find the information they need to operate profitable businesses.

New Orleans is near the heart of the gas turbine community and dear to the hearts of everyone who ever visited this magnificent city. Many users are expected to attend. If you operate turbines for a profit, come and join the activities. ✧

# TURBO EXPO

... Continued from page 1



## Outstanding Technical Congress (June 4-7) ... continued

For ASME TURBO EXPO in New Orleans, more than 500 refereed technical papers will be assembled into 115 technical sessions and presented over the four days of the event. These paper sessions will be complemented by 25 panel and discussion sessions, and a separate Gas Turbine Users Symposium (discussed later). The 140 total sessions of the Technical Congress will cover all aspects and all applications of gas turbine technology. For convenience, however, 50 of these sessions will be focused into 8 Power Generation Tracks, including one on distributed generation and micro turbines (see Abbie Layne's article on page 17). You can register online for this truly outstanding Technical Congress at: [www.asme.org/igti](http://www.asme.org/igti).



## Dynamic Keynote Session (June 4)

The Joint TURBO EXPO / IJPGC Keynote Session will be held Monday afternoon, June 4, from 2:00 – 4:30 pm, and is free to all registrants at ASME TURBO EXPO and IJPGC. This year four distinguished keynoters will address the theme, "New Horizons for Global Power - Manufacturer-User Dialogue" and a high-level representative of the U.S. Department of Energy will summarize the comments and relate them to upcoming DOE plans. Bob Kielb discusses this further in his "View from the Chair" on page 2 of this newsletter.

## Focused Gas Turbine Users Symposium (June 4-7)

The Gas Turbine Users Symposium (GTUS) has been developed especially for those involved in the on-site operation and management of gas turbines and related equipment. Twenty-two sessions in three fast-paced tracks over four days encourage discussion and sharing practical experience. Sessions include panels, tutorials and discussion groups, but no paper presentations.

Participants will discover ways to improve the profitability of gas turbine operations and ownership with the latest technology and practices, develop networks with other users, acquire technology to solve day-to-day problems, and enhance individual career performance. Details of the program and the formation of a GTUS Advisory Group are discussed in other articles in this newsletter.

If you now use or will soon use gas turbines, you and your colleagues should make the time to attend this important event. You may register separately online for the GTUS; but if you sign up for the Technical Congress, the GTUS sessions are included.

## World-Class Exposition (June 4-6 only)

More than 250 worldwide companies will be available in the exhibit hall for profitable discussion and problem solving during the three-day Exposition. A historic display, devoted to gas turbine inventors Von Ohain and Whittle, will guide your entry into the exhibit hall where these companies will display the newest and best gas turbine products and services available to the industry. Because the Exposition will include both ASME TURBO EXPO and the IJPGC Exposition, you can view a broader than usual range of other land-based power products and services. Entry into this world-class Exposition is free if you register for the Technical Congress or the GTUS. Otherwise, obtain complimentary passes from IGTI on-site or in advance.

ASME TURBO EXPO—Land, Sea, and Air (TE '01) will be a unique event that brings together gas turbine technology and power generation from design concepts and cutting-edge technology through user issues and aftermarket services. So join the more than 4,500 gas turbine and power industry professionals from over 60 countries around the world who will be in New Orleans from June 4-7. Come enjoy the "Big Easy!" Register and make your hotel reservations today online at [www.asme.org/igti](http://www.asme.org/igti). ☆

**NOTE: To keep yourself current on this rapidly evolving program, visit our web site at [www.asme.org/igti/events/te2001](http://www.asme.org/igti/events/te2001). Click on "Sign Up for E-Bulletin" in the left margin for automatic email notification of updates.**

## Distinguished Panel to Discuss Aircraft GT Maintenance & Repair

**M**r. Otha Davenport is responsible for all U.S. Air Force engines in development, acquisition and operation throughout the world. Mr. Davenport will chair a world-class panel at TE'01 to discuss current engine maintenance practices, continuing improvements, and the expected advanced technology enhancements for future engines.

Other panelists include: Jason Chamberlain, Director, Pratt and Whitney Engineering, East Hartford; Scott Crislip, General Manager, GE, Evendale; David Garrison, General Manager, Propulsion Engineering, Delta Airlines, Atlanta; Jim Uhl, General Manager, Power Plant Engineering, United Airlines, San Francisco; and Dave Pauling, SES Head of Propulsion and Power Engineering, U.S. Navy (NAVAIR), Patuxent River, MD.

This "manufacturer-user" dialogue will parallel the New Orleans Keynote Session, but focus on aircraft gas turbine maintenance, overhaul, repair, and reliability of both commercial and military jet engines operating on many aircraft platforms. Affordability and maintaining aging engine systems will also be discussed. No one interested in aircraft engines can afford to miss this panel discussion! ✧

## GTUS Advisory Group to be Formed at TE'01 in New Orleans

**O**f great interest to gas turbine users is the formation of an Advisory Group for the Gas Turbine Users Symposium (GTUS). Here is your chance to be heard on GTUS programming! The organizational meeting of this Group is planned for TURBO EXPO 2001 in New Orleans. All gas turbine users, in all applications of gas turbine technology, are invited to participate. This is a ground floor opportunity to get involved with the establishment of gas turbine users in prominent positions at TURBO EXPO for many years to come. The mission of the GTUS Advisory Group is:

- To provide a voice within IGTI representing the community that operates and applies gas turbines for commercial purposes.
- To encourage gas turbine users to participate in TURBO EXPO by planning and organizing information exchange sessions for the Gas Turbine Users Symposium (GTUS).
- To plan activities that enable gas turbine users to develop networks for sharing problem solutions.
- To develop venues for gas turbine users to discuss technical issues with equipment suppliers, service providers, and consultants.

Stay tuned to the IGTI web site ([www.asme.org/igti](http://www.asme.org/igti)) and the TURBO EXPO Final Program for meeting details. ✧

## DOD to Honor Aircraft Turbine Pioneers and Share Vision for the Future

**T**he Air Force Research Laboratory (AFRL) is sponsoring a display honoring the accomplishments of Dr. Hans von Ohain and Sir Frank Whittle at the entryway to the Exposition in New Orleans. The display will highlight historical firsts in gas turbine engine development and the role of military necessity as a technology driver.

The role of the Integrated High Performance Turbine Engine Technology (IHPTET) program in achieving the enormous performance gains demonstrated in recent aircraft gas turbine engines will be highlighted, as will the Versatile, Affordable, Advanced Turbine Engines (VAATE) program ... a multi-agency vision for future aircraft gas turbine engines that addresses performance and emphasizes affordability. ✧

## Due Diligence and Risk Taking Service to be Introduced at TURBO EXPO

**A** new, online system, to perform technical and commercial due diligence in support of project financing is being developed. The system will be capable of handling infrastructure projects and assets worldwide, having an initial focus on greenfield gas turbine based electricity generating projects. It will focus in the use of a consistent, transparent and standardized methodology for all capital projects.

Representatives of this system will participate in one of the Business and Economic Strategy panels as part of the Gas Turbine Users Symposium at ASME TURBO EXPO '01. Look for it. ✧

# IGTI/IJPGC/WEC Joint Panel on Reliability ... Why Should We Care? *The \$100,000,000 Answer and Beyond!*

by Bob Richwine, Senior Reliability Consultant  
Mirant Corporation

During the upcoming TURBO EXPO a panel session will be held entitled "Measuring Reliability in Today's Market," co-sponsored by IGTI, the ASME Power Division Reliability Committee, and the World Energy Council Performance of Generating Plant Committee. Panelists from diverse areas of the power generation supply chain will discuss the shortcomings of current reliability measures with particular attention focused on gas turbines. Panelists will offer suggestions for new measures that could more accurately connect a plant's reliability to the grid's reliability and to the plant owner's profitability.

Power plant owners increasingly ask, "Why should I collect and share my plant's reliability data when that could potentially hurt my competitive position?" The answer is that although there is a cost and risk associated with gathering and sharing such information, it is outweighed by the sounder, fact-based, foundation established for making effective business decisions. This has been demonstrated many times in the past when there was little real competitive pressure inhibiting the sharing of such data.

For example, equipment manufacturers use operational data to identify and correct design flaws in new machines. By applying learning curve theory to that historical data, we have been able to anticipate the amount of improvement that more recent versions of even newer machines will exhibit. Similarly, AE's have used reliability data to optimize the design configuration of new plants as well as to evaluate the cost-effectiveness of proposed design modifications.

Other studies have quantified the reliability impact of changing a plant's mode of operation so as to help evaluate the economic trade-off of cycling vs. base load operations.

Additionally, my company was able to employ other statistics to validate that our power plants were much more reliable during periods of peak demand, because there was a much greater economic incentive during those periods. Using this information, the company was able to reduce its reserve margin planning criteria by one full percentage point without reducing customer service reliability by simply taking advantage of what our plants were already achieving. For our 30,000+ MW system, this saved over \$100,000,000. This study was subsequently extended to the entire industry in North America and the results were similar for most utilities.

It is clear that data collection and analysis will be even more important in the future. Experts will find that linking technical performance to economic value in order to improve decision-making in a market-based, competitive environment can spell the difference between corporate success and failure. In this evolving business climate new players, such as risk managers, traders, marketers and asset managers, will join traditional players, like lenders, insurers, manufactures, AE's and operators, in recognizing the business advantages of using this data. But, as important as it is to collect and share data, collecting just any data can be misleading. It is essential that the "right" data be collected in order to produce "meaningful" statistics. The panel hopes that by exploring the reliability data issue from multiple perspectives the industry will move toward consensus in developing and adopting more useful reliability measures. ✧

*This important panel is part of the TURBO EXPO Technical Congress, the Gas Turbine Users Symposium, and the IJPGC Technical Program.*

RELIABILITY



# World Gas Turbine Industry Production Trends and Key Factors – 2001-2010

Approximate 40 Page Report

Price: \$295.00

In cooperation with Forecast International/DMS, the IGTI Board of Directors is pleased to announce the upcoming availability of the above gas turbine industry forecast. The report will be prepared by the Forecast International Power Group for review by the IGTI Board of Directors in preparation for ASME TURBO EXPO 2001 in New Orleans, LA. The data used to prepare the report will be effective as of May 2001, and will be drawn directly from the company's *Gas Turbine Forecast* service, as well as from associated databases and other sources.

## Table of Contents:

- Format
- Executive Summary and Market Overview
  - World Gas Turbine Industry 2001-2010
  - Market Shares of Industry Participants
  - General Industry Information
- Aero Engines
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  - Key Factors/Trends, Aero Engines
- Industrial & Marine Gas Turbine Engines
  - Breakdown by Power Band
  - Key Factors/Trends: Power Generation Market
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- Miscellaneous Applications Engines
  - Key Factors/Trends: Missile/Drone/RPV/UAV Gas Turbine Engines
  - Key Factors/Trends: Auxiliary Power Units/Ground Power Units
- Vehicular Propulsion/Rail Traction Turbines
- Appendix
  - Charts and Diagrams

**SPECIAL SHOW PRICE on-site at TURBO EXPO '01  
while they last...\$245.00**

To order your report directly from Forecast International, for delivery *after* TURBO EXPO, contact:

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**Disclaimer:** ASME and IGTI are not involved in the development of the above report, and are not responsible for the content. Contact Forecast International/DMS for a separate warranty statement.

## Bruce Buckland Celebrates 100 Years!

Born when the Wright Brothers were still building bicycles, and Chair of the (then) Gas Turbine Division Board of Directors long before IGTI had its office in Atlanta, Bruce O. Buckland celebrated his 100th birthday on December 15. As a member of ASME for 76 years, a Life Fellow and the 1975 recipient of the R. Tom Sawyer Award, he is a very special person.

**Congratulations!**

## Carol Russo Steps Down as ASME VP – IGTI

Dr. Carol Russo, recently elected ASME Vice President – IGTI, has resigned her position for personal reasons. In her letter of resignation, Carol mentioned that she regretted having to make the decision, but parental health issues made it impossible for her to devote the time necessary to fulfill her volunteer responsibilities. Carol served on the IGTI Board of Directors from 1993 to 1999 and was Chair in FY '97-'98. We wish her and her family well.

A replacement for Carol has been nominated by the IGTI Board of Directors and at press time is awaiting approval by ASME. ✪



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Published by the International Gas Turbine Institute  
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### MISSION STATEMENT

The International Gas Turbine Institute of The American Society of Mechanical Engineers is dedicated to supporting the international exchange and development of information to improve the design, application, manufacture, operation and maintenance, and environmental impact of all types of gas turbines and related equipment.

Special TURBO EXPO '01 Show Price ... On-Site Only ... \$45.00

# The History of Aircraft Gas Turbine Engine Development in the United States ... *A Tradition of Excellence*

by James St. Peter

*This absorbing, anecdotal history of gas turbine engine development spans over 50 years of scientific discovery, corporate intrigue, and insight into the minds of the historic personalities who shaped one of the great inventions of the 20th Century.*

## About the Book.

From the technological beginnings in England and Germany, through the proliferation of research and development in the United States, through the Great Engine Wars and the development of Mach 3 and stealth aircraft, to the modern IHPTET programs, this history draws upon the remembrances of those involved and a multitude of research sources that are quickly disappearing.

Included in the 600-page, hard-cover history are 19 chapters and 69 engine addenda, plus hundreds of photographs and illustrations, engine specifications and performance ratings, complete chapter endnotes, and a comprehensive index... ideal for reading, reference or continuing research.



## About the Author.

James St. Peter is a Technical Historian contracted by the Air Force to research and write this historical look into the development of aircraft gas turbine engines in the United States. He was ideally suited for this landmark project because of his in-depth knowledge of jet engines and previous research experience.

St. Peter was selected by the Air Force Wright Laboratory, Aero Propulsion & Power Directorate, at Wright-Patterson Air Force Base in Dayton, Ohio. The effort was co-sponsored and financially supported by the Army, Navy, Air Force, NASA, and the ASME International Gas Turbine Institute.



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# In Memory of Dr. John W. Sanborn

by Joseph Zelina, Honeywell Engines and Systems

**D**r. John W. Sanborn, Mesa, AZ, ASME Fellow, passed away December 19, 2000 after a courageous battle with Amyotrophic Lateral Sclerosis (ALS). John's involvement in ASME and other professional organizations spanned more than 25 years. He was selected as Vice Chair (1994) and Chair (1997) of the IGTI Combustion and Fuels Committee, and Environmental Chairman (1993) for the General Aviation Manufacturers Association.

John received his Ph.D. from the University of Massachusetts, Amherst in emissions and kinetics modeling. He managed the Combustion and Emissions group at Honeywell Engines and Systems, Phoenix, AZ, since 1983 and was the driving force in technological advancements of combustor durability, combustor aerothermodynamic modeling, and manufacturing techniques. Most recently, Dr. Sanborn became Manager of Combustion, Controls, and Fuel Systems at Honeywell Power Systems.

John was continually recognized throughout his professional career for innovative leadership, mentoring, work in the area of propulsion emissions regulations, technical publications, and combustion system design improvements. He is survived by his wife Pamela of 32 years, son Keith, daughter Sharon, daughter-in-law Lisa, and sister Jane Foskett. We will miss John very much. ✧



John Sanborn

## IGTI Board of Directors Endorses ...

### *"Turbo Fuel Cell"*

#### to Describe New Hybrid Technology

**A**t its most recent meeting, the IGTI Board of Directors passed a resolution to recommend the use of the name "Turbo Fuel Cell" to describe the power source combining a gas turbine with a fuel cell. It is hoped that by frequent use the term will become commonly accepted.

As George Opdyke, IGTI Treasurer, explained, "For some time, I have been troubled by the application of the name "hybrid" to a mixture of devices. For example, the name "hybrid" automobile is being applied to cars with both an I.C. engine and an electric motor." He goes on to explain that, in our business, "hybrid" cycles can include combinations of fuel cells with gas turbine engines, steam turbines, or even reciprocating engines. The terminology used for these combination systems has included "Hybrid Fuel Cell Systems", "Hybrid Systems", or even simply "Hybrids" ... all of which can be equally non-descriptive and confusing.

After surveying a variety of industry people with different backgrounds, the name "Turbo Fuel Cell" appears to be widely liked. It is properly descriptive, fairly short and easy to say. Thoughts and comments should be directed to George Opdyke at (203) 378-1243 or email: [gopdyke@netmeg.net](mailto:gopdyke@netmeg.net). ✧



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