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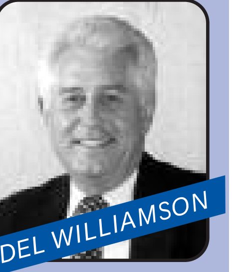
Outstanding ASME TURBO EXPO '01 Shaping Up for New Orleans

by Dilip Ballal, IGTI Chair of Conferences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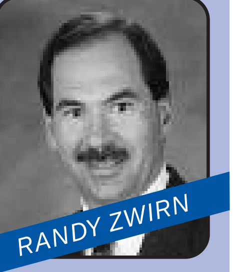
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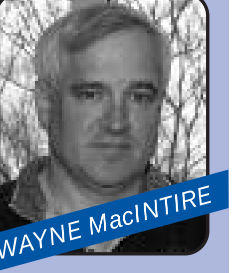

WAYNE MacINTIRE

Join the more than 4500 gas turbine and power industry professionals from over 60 countries around the world who will gather in New Orleans, Louisiana 4-7 June 2001 for the premier event of the international gas turbine community: ASME TURBO EXPO—Land, Sea & Air (TE'01). The theme "New Horizons in Global Power" will be prevalent throughout this dynamic four-day event covering everything about gas turbines. Highlights include: distributed power generation, micro turbines, fuel cells, design concepts, technical innovations, maintenance, repair, retrofitting, certification, after-market issues and much more.

Keynote Highlights

A joint TE'01 / IJPGC* Keynote Session will feature one of the most impressive groups of speakers ever assembled for an IGTI event! The Keynote theme will be, "New Horizons in Global Power … Manufacturer-User Dialogue." To address this theme, we are proud to have the participation of the following outstanding Keynote speakers:

- Del Williamson, President, GE Power Systems Global Sales
- Randy Zwirn, President & CEO, Siemens Westinghouse Power Corporation
- Larry Izzo, President & CEO, Enron Engineering and Construction Company
- Wayne MacIntire, Senior Manager Power Technology, International Paper, Inc.

These distinguished speakers will present the views of buyers and sellers in the power generation arena. Rita A. Bajura, Director of the National Energy Technology Laboratory of the DOE, will summarize the Keynoters' comments and relate future DOE activity to "New Horizons in Global Power." Audience questions will be taken by the Keynoters. Over 1,000 delegates are expected to attend this opening Keynote Session.


Rita A. Bajura

Technical Congress Highlights

Nearly 600 refereed papers assembled into 124 technical sessions and 22 panels, tutorials and discussion sessions will combine to provide the information you need for problem solving and career advancement. The program for New Orleans includes vital gas turbine issues, such as:

...continued on page 10

Value Added Knowledge

"Establish IGTI as the foremost provider of value added knowledge to the gas turbine community." This is one of the primary goals in IGTI's strategic plan. Although there is little argument that the TURBO EXPO Congress is the pre-eminent conference for the latest gas turbine technology, serving the knowledge requirements of the gas turbine community requires many more year-round services and activities. In addition to TURBO EXPO, IGTI currently offers a newsletter, scholarships, home study courses, and the annual Gas Turbine Technology Report & Product Directory. The IGTI Board of Directors, however, believes we need to do more.

We see the IGTI web site as a primary vehicle for providing the gas turbine community with easy access to increased gas turbine knowledge. As a result, the IGTI staff is completely revamping our web site. The web site under construction consists of five primary areas: Resources, Events, Services, Community, and IGTI Store.

Bob Kielb
Chair
IGTI Board of Directors

Debuting as a principal gas turbine resource is "SourceGT," an electronic industry reference for the exchange of gas turbine educational and technical information. SourceGT follows in the footsteps of IGTI's annual Technology Report & Product Directory which served as a leading gas turbine global report for over a dozen years. As a web-based resource, SourceGT listings can be added and updated continuously and thus offer the newest and best data to site visitors. Listings and web links of leading companies will be available by product and service category.

The "Events" area of the web site contains all of the necessary information on IGTI conferences. This will range from detailed descriptions of IGTI's Gas Turbine Users Symposium, Exposition, and Technical Congress to online registration. The job of putting the events together will be made more efficient through the use of electronic forms and reports available on an as needed basis through the "Community" pages.

Detailed descriptions of additional gas turbine resources can be found under "Services." These include not only ASME and IGTI offerings, but also other significant gas turbine publications and information sources. Descriptions of IGTI's popular Home Study Courses and its scholarship program will also be included.

The "Community" pages are designed for those who want to know more about, or become involved in, IGTI activities. Included is contact information about IGTI leaders and staff, details on committee structure and areas of responsibility, web-based program guides and forms, and access to the Gas Turbine Forum.

IGTI products previously ordered through the IGTI Atlanta office and all new products will now also be available for online purchase.

IGTI's revised and greatly expanded web site <http://www.asme.org/igti/> is scheduled for launch in early December 2000. Our vision is to make it your portal for any and all gas turbine information. We ask for your comments on the above, and for your ideas to help make IGTI the foremost provider of value added knowledge to the gas turbine community. Please mail your comments to me at <rkielb@duke.edu>.

Keep your turbines turning!

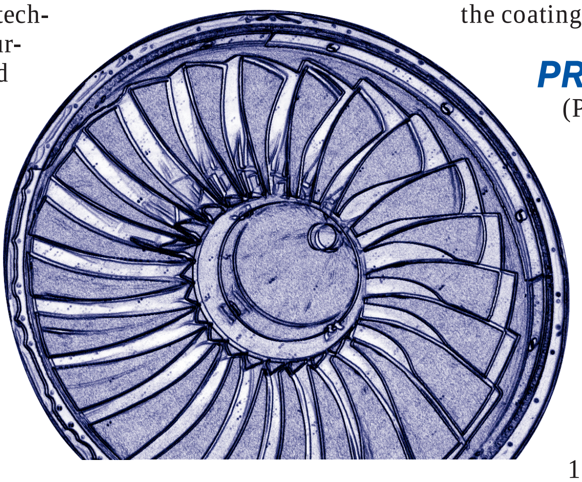
"*We see the IGTI web site as a primary vehicle for providing the gas turbine community with easy access to increased gas turbine knowledge.*"

CAPSTONE TURBINE CORPORATION has announced a licensing agreement with **SOLAR TURBINES INCORPORATED** to manufacture recuperators, an integral part of the Capstone MicroTurbine system. The companies have worked together for three years to develop advanced automated manufacturing techniques for the Solar-designed product.

PRATT & WHITNEY'S newest engine, the PW6000, took to the air for the first time August 21, successfully completing a one hour and 20 minute flight. The 16,000- to 24,000-pound thrust PW6000 is the launch engine for the new Airbus Industrie A318 100-passenger airplane. The A318/PW6000 combination will complete its certification and enter service in late 2002.

WILLIAMS INTERNATIONAL'S first FJ33 engine in its new family of 1200 to 1500-pound thrust turbofans successfully completed its first test run on July 26. The engine demonstrated favorable margin to fuel consumption goals, displayed very low vibration, and very low oil consumption, besides exceeding thrust targets. The FJ33 is being developed to power a new class of light jets in the 5000-to-9000-pound gross-takeoff-weight class.

CATALYTICA COMBUSTION SYSTEMS, INC., a subsidiary of Catalytica, Inc., has been awarded $1.6 million under a U.S. Department of Energy sponsored program to help fund research and development of durable and cost-effective low emissions technologies for small gas turbines used in distributed power generation. The project will focus on catalyst life extension, cost reduction, and application of Catalytica's Xonon Cool Combustion™ technology.



The team of **HONEYWELL** and **GENERAL ELECTRIC** have won the Army's $3+ billion Abrams-Crusader Common Engine (ACCE) program, winning out over competitors Caterpillar and the team of General Dynamics and MTU. Under the program, the Honeywell-GE (HGE) team will replace the Honeywell AGT 1500 vehicular gas turbine in the Army's M1 Abrams main battle tank and the Caterpillar Perkins Condor CV12 diesel engine intended for the Army's XM2001 Crusader 155 mm self-propelled howitzer. Upwards of 2,800 M1 tanks, and about 825 howitzers and resupply vehicles are to be covered by the ACCE program. The HGE team will redevelop the LV100 design for the ACCE program under the Army's $195.6 million contract awarded on September 20.

SIEMENS WESTINGHOUSE POWER CORPORATION and **CHROMALLOY GAS TURBINE CORPORATION**, a subsidiary of Sequa Corporation, are forming a joint venture to support the growth of the Siemens gas turbine fleet. Siemens owns 51 percent of Turbine Airfoil Coating & Repair LLC (TACR), which will provide for the repair of Siemens industrial gas turbine blades and vanes, the coating of repaired components, and the coating of new blades and vanes.

PRATT & WHITNEY CANADA CORP. (P&WC) marked an important milestone in its 72-year history on November 16 with the delivery of its 50,000th engine. The engine, a PT6A-67D, was delivered to **RAYTHEON AIRCRAFT**. Raytheon (Beech) 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. Pratt Canada currently produces an average 2,000 engines a year.

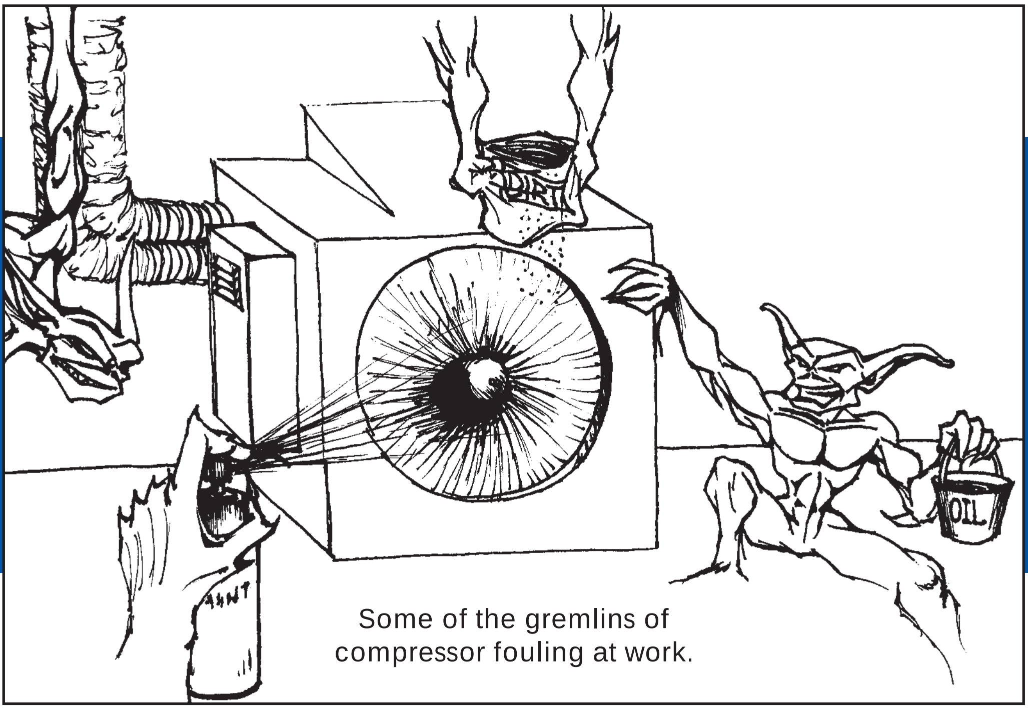
S&S ENERGY PRODUCTS has announced a new addition to its LM product line, the 18-megawatt GE LM2000 aeroderivative gas turbine-generator set. A derating of GE's popular LM2500, the LM2000 will offer 18 megawatts for power generation, 24,000 shaft horsepower for mechanical drive uses, and a 35.5% thermal efficiency. The engine will have a lower firing temperature with hot section replacement intervals expected to be extended to approximately twice those of the LM2500.

PRATT & WHITNEY SMALL MILITARY ENGINES (SME) and **TELEDYNE CONTINENTAL MOTORS** (TCM) have signed a Memorandum of Agreement to pursue teaming in areas of development, manufacturing, and technical and product support of small military engines products and services. This product line would include Uninhabited Air Vehicle (UAV) engines up to 16,000 pounds of thrust for U.S. Government customers. ✢

Gas Turbine News in Brief ... is compiled for Global Gas Turbine News *by Carl E. Opdyke, Power Systems Aerospace Analyst, FORECAST INTERNATIONAL, 22 Commerce Road, Newtown, Connecticut 06470*

COMPRESSOR FOULING ... CAUSES AND SOLUTIONS

by Cyrus B. Meher-Homji, P.E., ASME Fellow
Chief Engineer, Gas Turbine Division of Mee Industries, Inc.



Some of the gremlins of compressor fouling at work.

The fouling of axial flow compressors is a serious operating problem in gas turbines and its control is of supreme importance to gas turbine operators especially in the current deregulated and highly competitive power market. Foulants, even in the parts per million (ppm) range, can cause deposits on the blading, resulting in a severe performance deterioration (decrement). The effect of compressor fouling is a drop in airflow and compressor efficiency, which results in a drop in power output and thermal efficiency. In some extreme cases, fouling can also result in surge problems. This article discusses the mechanism of fouling, the effects, types of foulants, detection methods and control techniques. A brief discussion on turbine fouling is also presented.

INTRODUCTION

Gas turbines ingest large quantities of air. The solids or condensing particles in the air and in the combustion gasses can precipitate on the rotating and stationary blading causing changes in their aerodynamic profile, dropping the compressor air mass flow rate and affecting efficiency. This has an adverse effect on the unit's performance. The output of a gas turbine can drop by as much as 10%. Moreover, contaminated air can cause a host of problems that include erosion, fouling, corrosion and, in some cases, plugging of the hot section cooling passages.

Some estimates have placed fouling as being responsible for 70 to 85 % of all gas turbine performance loss accumulated during operation. System output losses range between 2% (under favorable conditions) and 15 to 20 % (under adverse conditions). In a gas turbine about 50 to 60 % of the total work produced in the turbine section is utilized by the compressor; therefore, maintaining high compressor efficiency is an important contributing factor to the plant's revenue stream.

> ***"A 75 MW unit located in an industrial environment with air loading of 10 ppm will ingest 594 lbs. of particulates in a day."***

CAUSES OF FOULING

Experience has shown that axial compressors will foul in most operating environments, be they industrial, rural or marine. There are a wide range of industrial pollutants and a range of environmental conditions (fog, rain, humidity) that play a part in the fouling process.

Compressor fouling is typically caused by:

- Airborne salt.
- Industrial Pollution - fly ash, hydrocarbons, smog, etc. This causes a grimy coating on the early stages and can get "baked on" in the latter stages (especially in high pressure ratio compressors).
- Ingestion of gas turbine exhaust or lube oil tank vapors.
- Mineral deposits.
- Airborne materials - soil, dust, sand, chemical fertilizers, insecticides, insects and plant matter.
- Internal gas turbine oil leaks - axial compressor front bearing is a common cause. Oil leaks combined with dirt ingestion cause heavy fouling problems.
- Impure water from evaporative coolers.
- Coal dust and spray paint that is ingested.

The fouling rate for a compressor will be a strong function of the environment, the climatic conditions, the wind direction and the filtration system. A 75 MW unit located in an industrial environment with air loading of 10 ppm will ingest 594 lbs. of particulates in a day.

Ambient air can be contaminated by solids, liquids and gases. Air loadings can be defined in mg/m^3, grains/1000 ft^3 or ppm (mass of contaminant per unit mass of air). In general, particles up to 10 microns cause fouling, but not erosion. Particles above 10 to 20 microns cause blading erosion. Some typical air loadings are: country 0.01 - 0.1 ppm by weight; coastal 0.01 - 0.1 ppm by weight; industrial 0.1 - 10 ppm by weight; and desert 0.1 - 700 ppm by weight.

As air passes through the intake and filtration system, it proceeds at a very low velocity. As it approaches the compressor face, the air accelerates to a high velocity (0.5 - 0.8 Mach number). This results in a static temperature reduction of about 10-15 C. The saturation air temperature also drops. If the static air temperature falls below the saturation air temperature, condensation of water vapor occurs. This is a common occurrence in most gas turbines when the relative humidity is even above 50%. Also, the filters tend to unload salt (leeching effect) under high humidity conditions and this is an associated factor that is often neglected. Particles then form nuclei for the water droplets and start to adhere to the blading. As the air progresses to the rear compressor stages, it gets hotter and drier, typically causing less fouling in the latter stages.

Marine and Offshore Environment

The offshore environment is particularly challenging. Airborne salt can exist in three basic forms: aerosol, spray, and crystal. Aerosols can range in size from 2 microns to 20 microns (1 micron = 10^{-6}m or 1/1000 mm). Aerosols are generated by bubbles shattering on the sea surface. Sea spray generates large droplets (sized 150 to 200 microns) and these tend to drop out due to gravity. Sea salt crystals absorb moisture under appropriate relative humidity conditions. The size of these peak in the range of 2 microns. The relative humidity off-shore was found to be almost always high enough to ensure that salt was in its wet form. Studies by Tatge, et al concluded that salt would stay as supersaturated droplets unless the relative humidity dropped below 45%.

The environment on off-shore platforms is not "dust free" and can include flare carbon and mud burning foulants (which can be a problem with poorly positioned flare stacks and with sudden changes in wind direction), and drilling cement and other dusts (which can be blown around a rig). Grit blasting has also been a serious problem.

EFFECTS OF FOULING

Fouling of axial flow compressors can affect the aerothermodynamics of the gas turbine, promote compressor surge, and affect blading integrity.

Aerothermodynamic Effects

The axial flow compressor is a sensitive component that requires smooth aerodynamic surfaces. Fouling causes an alteration in the shape of the blading which reduces airflow rate, pressure ratio and compressor efficiency. The overall effect is a drop in thermal efficiency (increase in heat rate) and a drop in output.

An axial compressor is a machine where the aerodynamic performance of each stage depends on the earlier stages. Thus, when fouling occurs in the inlet guide vanes and the first few stages, there may be a dramatic drop in compressor performance. This can often occur when oil and industrial smog or pollen are present and form an adhesive wetting agent. The early stages are often the worst fouled stages. If the rear stages foul, this seems to have a smaller impact on performance; but due to higher temperatures, deposits can get baked on and become difficult to clean. This baking effect is more severe on the high pressure ratio (18 to 30:1) aeroderivative

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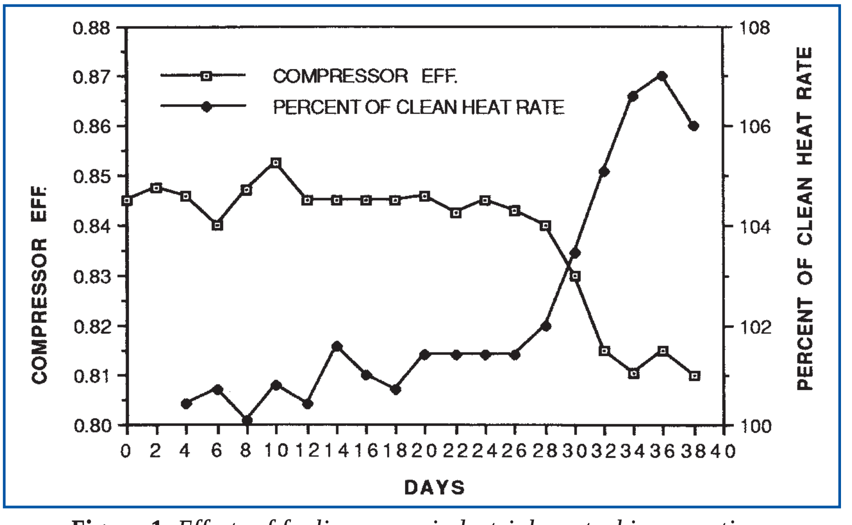


Figure 1: *Effects of fouling on an industrial gas turbine over time.*

Dundas [1986] has conducted an excellent analytical investigation into the deterioration of turbine operation including drop in compressor efficiency, fouling, 1st stage nozzle distortion, internal bleed seal deterioration, drop in turbine efficiency, inlet filter fouling and low fuel heating value. These were examined to study the effect on the turbine operating line. His study concluded that compressor fouling had a pronounced effect on the operating line.

While these effects cause the movement of the operating line toward the surge line, there are other factors that can cause movement of the surge line itself. Erosion of compressor blading can effect boundary layer development and increase the tendency toward separation. Stall can therefore occur at lower incidences than with smooth compressor blading. Heavy erosion can also reduce blade tip chords, thereby reducing blade tip solidity, which would adversely effect stage stability.

machines than on the heavy duty industrial gas turbines (with typical compressor ratios of 10 or 14:1).

Figure 1 *(on page 5)* shows a fouling process that occurs in a large gas turbine engine. This graph illustrates the changes in compressor efficiency and heat rate over time. The higher the heat rate the lower the overall gas turbine efficiency.

Compressor Surge

As fouling drops the airflow in the first stage, this affects the performance of the latter stages. The first stage pressure ratio is thus increased. This causes a higher density at the inlet to the second stage. Thus there will be a further reduction in second stage flow coefficient. This effect progresses through successive stages until a later stage stalls triggering a surge. *(See Dundas sidebar to the left.)*

The importance of considering fouling effects on surge as a problem becomes more important with the use of gas turbines in combined cycle or cogeneration applications utilizing inlet guide vane (IGV) control and steam injection.

There have been several cases where excessive distortion of the inlet airflow has triggered a surge event resulting in compressor damage. Icing, causing uneven inlet circumferential distortion, or uneven clogging of filters, possibly due to a bend in the inlet duct before the filter or improper inlet system design, can create distortion effects which could result in surge.

Blading Integrity Effects

While fouling cannot be said to be a major cause of blading failure, it can contribute to blading problems:

a) … by promoting surge or rotating stall which might have a dangerous effect on blades.

In some unusual cases, blading natural frequencies can be affected by the increase in mass due to dirt buildup on the blading causing mechanical distress.

b) … by excessive dirt on the blading causing imbalance and a consequent increase in running speed vibration. In some cases dirt can get between the bearing surfaces of the blade root, causing the blades to operate in a non-normal position, which would add to the stresses. If the root constraint is changed due to buildup in the fir tree region, a change in natural frequency could result (as the boundary condition changes).

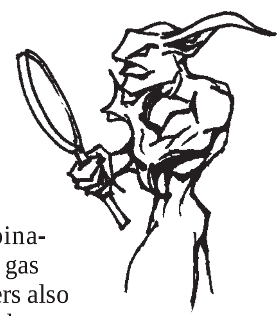
c) … by blocking or partial blocking of cooling passages of hot section stators and blades. As cooling air is bled from the compressor, foulants such as cement dust, coal dust and fly ash can enter the cooling system. The effects can be improper cooling and accelerated thermal fatigue, though typically the effects are gradual in nature.

d) … by leading to a serious corrosion problem, especially with poor filtration and high humidity. Corrosion will occur if salt water or salt particles (1-3 microns in size) are ingested into the compressor. The dry salt or brine will absorb moisture during high humidity operation or during water washing. Corrosion is caused by the chemical reaction between the engine components and airborne contaminants. Salts, mineral acids and aggressive gases (e.g. chlorine) along with water can cause wet corrosion and compressor blade pitting. This can lead to local stress raisers which can diminish blade fatigue life. An important corrosion process in compressors is known as electrochemical or “wet corrosion”.

e) … by causing erosion. Particle sizes of 5-10 microns represent the transition zone between fouling and erosion. (Note: 10 microns = 1/15 diameter of human hair.) Erosion impairs aerodynamic performance and can affect the blade mechanical strength. Erosion first increases blading surface roughness thus lowering efficiency slightly. As erosion progresses, airfoil contour changes occur at the leading and trailing edge as well at the blade tip. Severe erosion has also been known to cause changes in blade natural frequency.

f) … by indirectly contributing to Foreign Object Damage (FOD). Though not linked to fouling directly, this is mentioned because it could be caused by a loss in filter integrity. Damage is typically to the early compressor stages, though in some cases the foreign object works its way to later stages also and causes damage. Damage is a function of size, foreign object composition, blade construction and impact location. It can lead to direct or secondary failure. Foreign object damage can be caused by ice, failed intake section components, materials and tools left in the inlet plenum.

DETECTION OF FOULING



Gas turbine manufacturers and operators typically develop guidelines as to when fouling deterioration calls for corrective action. This is usually based on a combination of load and exhaust gas temperatures (EGT). Users also monitor compressor discharge pressure and compressor efficiency. Graphs can be plotted to show expected (clean) vs measured parameters.

It is the opinion of some operators that the only way to detect a fouled compressor is by visual inspection. With most turbine designs, however, this means shutting the unit down, removing the inlet plenum hatch and visually inspecting the compressor inlet, bellmouth, inlet guide vanes (IGVs) and visible early stage blading.

The following factors can be used as indicators of fouling: a) Drop in compressor air (mass) flow rate on fixed geometry engines, and b) Drop in compressor efficiency and pressure ratio. The most sensitive of these parameters is the airflow rate.

The real problem is to detect fouling at an appropriate time before a significant power drop has occurred and a fuel penalty cost has been paid. Several philosophies are in use. Some operators believe in periodic washing of the machine while others base washes on condition (i.e. some set of performance parameters). The philosophy utilized is a function of normally expected fouling level, its severity, washing effectiveness and plant operation criteria. Measurement of air-intake depression is a practical and economical method for fixed geometry machines. The technique involves measuring intake depression as an analog of airflow rate. In this approach, the gas turbine inlet bellmouth is utilized as a flowmeter.

CONTROL OF FOULING

Fouling is best controlled by a combination of two methods. The first line of defense is to employ a high quality air filtration system. If fouling occurs (and it usually will) then the compressor can be washed.

Filtration

Filters can be categorized as follows:

Inertial Filters: The objective here is to make the air change direction rapidly causing separation of dust particles. These filters are permanently fixed and require minimal maintenance. Inertial filters typically operate at face velocities of 20 ft/second.

Prefilters: These are medium efficiency filters made of cotton fabric or spun fiberglass. They are relatively inexpensive and serve as "protection" for high efficiency filters.

Coalescers: These are constructed by the use of wire mesh which acts as an agglomerater. The mist in the inlet air is agglomerated and the moisture is thus removed.

Louvers and Vanes: These are typically used in the first stages along with coalescer filters to remove water droplets.

High Efficiency Filters: These filters remove smaller particles of dirt. They are typically barrier or bag type filters.

Self-Cleaning Filters: These consist of a bank of high efficiency media filters. Air is drawn through the media at a low velocity. At a predetermined pressure drop (about 2-3" Water Gauge) a reverse blast of air is used to remove dust buildup.

Air tightness is a must for any gas turbine inlet system because even the most efficient filtration system will be useless if unfiltered airflow enters the compressor. Some common causes of leakage are: bypass door leakage; poor gaskets and seals at flanged points; and modifications made on the inlet ducting. In this latter case, over the years personnel may add structures or devices to the inlet system which might cause problems.

Corrosion in carbon steel inlet ducts has also been a source of problems. At times the corrosion can be severe enough to cause a loss of integrity. Because of this, several users are now using 316L stainless steel for the filter houses and inlet ducts, which is a cost effective thing to do in the long term. The effectiveness of a filtration system is impacted by its design, installation and maintenance. *(See the sidebar about intake filter design on page 8)*.

Figure. 2: *High performance filter housing made of 316L stainless steel.* (Courtesy Altair Filter Technology)

Compressor Washing

This is an area in which strong opinions exist. Washing efficacy is so site specific that approaches that work for one operator may not be appropriate for another. Much controversy is often caused by polarized opinions relating to wash approaches, wash media and techniques. Some of the highlights are examined below in an attempt to present the overall picture. Operators must often determine the best approach for their gas turbines by trial and error in terms of wash technique, use of online washing, what should be used, and the frequencies of wash. This is a complex technical-economical problem also depending on the service that the gas turbines are in. IPP operators and Merchant Power plants may need to be more aggressive in controlling fouling because they typically lack the ability to be shut down for crank washes.

Two approaches to compressor cleaning are abrasion and solvent cleaning. Because abrasive cleaning has diminished in popularity, liquid washing will be the primary focus.

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Some important considerations in intake filter design are...

✶ Aerodynamic design should be such as to keep intake velocities uniform across the entire filter area.

✶ Filter housing should be of a bolted and welded design fabricated of steel no less than 3/16” thick and reinforced by steel members. Filter house should withstand 12” water gauge pressure. All seams and joints should be air tight. All nuts and bolts used inside the clean air plenum should be welded after assembly to prevent air leaks and foreign object damage to the turbine.

✶ Design should facilitate change-out of all filters from the upstream side. Filter change should be possible without turbine shutdown. Filter elements should be designed for quick change-out and the avoidance of blind assembly, loose retaining nuts, ungasketed washers, etc.

✶Filter design should ensure that the inlet air is drawn at least 10 feet above grade level. (In some locations a greater height may be required.)

✶ A stainless steel trash screen with 1” square mesh should be provided in the transition section between the clean air plenum and the compressor intake.

✶ Avoid the use of gravity weighted by-pass doors. Bypass doors are designed to permit emergency airflow to the engine when intake pressure drop rises above a critical value. Bypass doors are typically gravity operated or power operated. The gravity type has earned a reputation for unreliability. Poor sealing, hinge corrosion and improper operation have made the bypass door a weak link in inlet filter design. Many users have done away with by-pass doors.

✶ All filter seal points should be reviewed during the design phase. Poor intake sealing has allowed leaks through bypass doors, access doors and flanges on the intake filter. Several times flange distortion has allowed air ingress. Users should specify types of seals required and call for a filter house integrity test under specified depression to ensure airtightness.

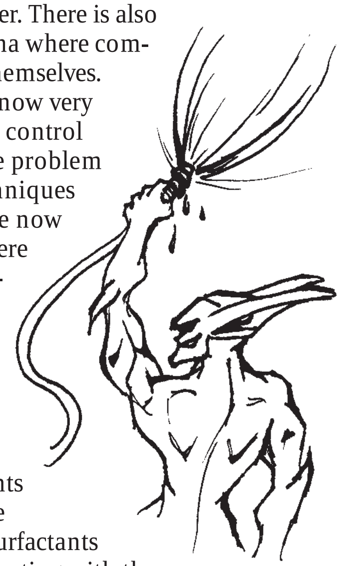
✶ System design in the case of pulsed cleaning systems, should be such as to minimize flow distortions and pressure pulsations due to pulse cleaning. More than 5% of the total filter elements should not be cleaned simultaneously.

✶ Filter system pressure drop is an important parameter affecting gas turbine performance. The following rough rules of thumb may be applied: For aero-derivative gas turbines, every 4” of inlet loss will result in a 0.7% increase in heat rate and a 1.6% reduction in power. For heavy duty industrial machines, a 4” inlet loss will result in a 0.6% increase in heat rate and a 1.6% drop in output power. It is important to consider both new filter pressure drop and the pressure drop increase over time.

Water washing (with or without detergents) cleans by water impact and by removing the water soluble salts. It is most important that the manufacturer’s recommendations be followed with respect to water wash quality, detergent/water ratio and other operating procedures. Typically, wheel space temperatures must be below 200 F to avoid thermal shock and the water wash is done with the machine on crank. Water washing using a water-soap mixture is an efficient method of cleaning. This cleaning is most effective when carried out in several steps which involve the application of a soap and water solution, followed by several rinse cycles. Each rinse cycle involves the acceleration of the machine to approximately 50 percent of the starting speed, after which the machine is allowed to coast to a stop. A soaking period follows during which the soapy water solution may work on dissolving the salt.

A fraction of airborne salt always passes through the filter. The method recommended for determining whether or not the foulants have a substantial salt base is to soap wash the turbine and collect the water from all drainage ports available. Dissolved salts in the water can then be analyzed.

Certain filters, during periods of high humidity, were found to “dump” contaminants into the machine, causing a drop in power. There is also evidence of phenomena where compressors can “clean” themselves.



Online washing is now very popular as a means to control fouling by keeping the problem from developing. Techniques and wash systems have now evolved to a point where this can be done effectively and safely. Washing can be accomplished by using water based solvents, petroleum based solvents, or surfactants. The solvents work by dissolving the contaminants while surfactants work by chemically reacting with the foulants. Water based solvents are effective against salt, but fare poorly against oily deposits. Petroleum based solvents do not effectively remove salty deposits. With solvents, there is a chance of foulants being redeposited in the latter compressor stages.

Even with good filtration, salt can collect in the compressor section. During the collection process of both salt and other foulants, an equilibrium condition is quickly reached, after which reingestion of large particles occurs. This reingestion has to be prevented by the removal of salt from the compressor prior to saturation. The rate at which saturation occurs is highly dependent on filter quality. In general, salts can safely pass through the turbine when gas and metal temperatures are less than 1000 F. Aggressive attacks will occur if the temperatures are much higher. During cleaning, the actual instantaneous rates of salt passage are very high together with greatly increased particle size. *(See sidebar at right)*.

TURBINE SECTION FOULING

While turbine section fouling is not typically a serious problem with natural gas fired gas turbines, contaminants that cause turbine fouling can enter the gas turbine through the inlet air, or through the fuel (if liquid), fuel additives or NOx control injection fluid.

In the hot turbine section, and in the presence of hot gases, low melting point ashes, metals and unburned hydrocarbons can be deposited in the form of scale. As hot combustion products pass through the first stage nozzle, they experience a drop in static temperature and some ashes may be deposited on the nozzle blades. Because the throat area of the nozzle controls the compressor-turbine matching, a reduction in throat area causes a movement away from the design match point. This then causes a loss in performance. Deposits will also form on the rotating blades causing a further loss in performance.

Blade and disc cooling can also be impaired by foulants causing a reduction in component life or even failure. Because the fuel flow rate is typically about 2% of the air mass flow rate, 1ppm Na entering from the fuel would have the same effect as just 20 parts per billion (ppb) airborne salt entering the airflow. This is a significant requirement considering that most manufacturers call for not more than .5 ppm of Na. Turbine section fouling is accentuated when heavy fuels are used and inhibitors (used to counteract the presence of Vanadium) cause ash buildup.

CONCLUSION

With ever increasing fuel costs, the need to control fouling (which is a form of recoverable deterioration) is of paramount importance. Being a very site-specific issue, users should be aware of all factors involved, and select those tools that can best control and minimize their particular problems. ✯

References:

Meher-Homji, C.B., (1990), "Gas Turbine Axial Compressor Fouling – A Unified Treatment of its Effects, Detection and Control," ASME COGEN TURBO IV, New Orleans, August 27-29, 1990, Publication IGTI Vol. 5.

Dundas, R.E., (1986), "A Study of the Effect of Deterioration on Compressor Surge Margin in Constant Speed, Single Shaft Gas Turbines," ASME Paper No.: 86-GT-177.

Some important practical considerations for compressor washing:

- ✶ Ensure that nozzles do not create wakes that could disturb compressor airflow. It is advantageous to locate them in lower velocity areas to ensure effective misting of cleaner. Wash system manufacturers would have valuable insight into how and where nozzles should be placed.
- ✶ If online washing is used, it is best not to wait until foulants get a chance to build up. The optimal schedule is machine/ environment dependent and no firm guidelines can be given. It could range from a daily wash to much larger intervals.
- ✶ Examine the spray nozzle design to ensure that there is no chance of it coming loose and creating a FOD incident.
- ✶ Stainless steel for tanks, nozzles and manifolds are recommended to reduce corrosion problems.
- ✶ If the commercial cleaner being used requires dilution, the quality of the dilution water is important. Strength and wash intervals should be adjusted based on performance improvements.
- ✶ Prior to washing a very dirty compressor, attempt to clean the inlet plenum and bell mouth prior to the wash.
- ✶ Carefully follow manufacturers requirements relating to drains, valving, protection of piping and flushing.

ASME TURBO EXPO LAND, SEA & AIR 2001

"TURBO EXPO '01" ...continued from front page

- Next generation intelligent engine controls
- Condition monitoring of combined cycle power plants
- Advanced gas turbines and novel cycles
- Ceramic components durability and life predictions
- Control of combustion instabilities
- Fuel cells and emissions regulatory issues
- Protective coating technology, fatigue, fracture, and life prediction
- Unsteady flows in turbomachinery
- and much more.

NOTABLE FEATURES: The Technical Congress will include a group of sessions developed by the IGTI Task Force on Distributed Power, and an exceptional panel on 21st Century Aircraft Gas Turbine Maintenance & Repair. Each feature is discussed more fully elsewhere in this newsletter.

Keynote Session at TURBO EXPO 2000 in Munich, Germany.

Gas Turbine Users Symposium (GTUS) Highlights

To organize the Gas Turbine Users Symposium (GTUS) for TE'01, IGTI has marshaled 20 hand-picked advisors representing power utilities, IPPs, gas transmission, oil and gas production, and petrochemical industries from four continents to develop a high-impact forum to benefit gas turbine operating enterprises throughout the world. The GTUS's 24 panel, tutorial and discussion sessions are presented in three program tracks: "Performance Enhancement and Preservation" … "Hot Section Repair and Integrity" … and … "Business and Economic Strategies." Session highlights include:

- Monitoring, Diagnosis, and Performance Testing
- Hot Section Failure Diagnosis; Materials and Coatings Selection
- Maintenance Strategies to Improve Reliability and Minimize Life Cycle Costs
- Emissions Control and Operating Experiences
- Fouling, Filtration, Washing, and Fogging
- Cogeneration and Combined Cycles
- Surge Control for Centrifugal Compressors
- and much more.

Winner of Palm VII at Thursday's drawing in Munich.

MORE GTUS HOT TOPICS: Long-term service agreements; conversions, modifications and upgrades; reliability measures in today's market; safety; risk management and insurance; networking among GTUS participants, and useful interactions with OEMs.

Stay up-to-date on TE'01 program developments by logging onto the IGTI web site at www.asme.org/igti/te2001. Revisit it often. Even better, at the site click on "Subscribe to E-Bulletin" to get automatic email notification of new postings, including the anticipated January availability of online registration and housing information. TE'01 in New Orleans will be another outstanding IGTI event, and we want to make it your best one ever! ✢

Part of the Exposition at TURBO EXPO 2000 in Munich last May.

** For 2001, ASME TURBO EXPO—Land, Sea & Air and the International Joint Power Generation Conference will co-locate their events. Plans call for a joint Keynote Session, a joint three-day Exposition (4-6 June), and separate technical congress registrations (with attendance cross-over privileges).*

New Focus on Distributed Power, Micro Turbines at TE'01 and Beyond

ASME TURBO EXPO LAND, SEA & AIR 2001

Forecast International predicts that within this decade, deregulation of power will create unprecedented demand for a small-power class (less than 1 MW) of micro turbines and fuel cells, both separate and combined. Today, it is possible to produce power close to its point of use, and this distributed power generation concept will radically transform the electricity business. Under the leadership of Dr. Norman Holcombe of the National Energy Technology Laboratory, U.S. Department of Energy, IGTI has established an ad hoc Task Force on Distributed Power to bring together for discussions and debate all aspects of this hot topic: micro turbines, hybrid engine cycles, fuel cells, control systems, alternate fuels and emissions, equipment design and development, and user experience.

Norm Holcombe

The 15 members of the task force are drawn from industry, academia, government, and the user community. Technical papers, panel discussions, tutorials, and exhibits covering numerous aspects of this distributed power revolution will form an important part of TE '01. In addition, top-level DOE personnel will participate in the Technical Congress and GTUS. Thus, the "Big Easy" will be the place to learn the latest about the newest!

IGTI Task Force on Distributed Power

Norman Holcombe, Chair
U.S. Department of Energy
National Energy Technology Laboratory

Industry ...

Tim Callahan, Southwest Research Institute
Sanjay Correa, General Electric
Mary Gerstner, Honeywell Power Systems
Anthony Leo, FuelCell Energy Inc.
Ron Natole, Natole Turbine Enterprises Inc.
Stephen Veyo, Siemens Westinghouse Power Generation
Leslie Witherspoon, Solar Turbines Inc.

Academia ...

Scott Samuelsen, Nat'l. Fuel Cell Research Center
University of California at Irvine
Riti Singh, Cranfield University, U. K.

Government ...

Debbie Haught, Department of Energy
George Richards, Department of Energy

Users ...

Jeffrey Hinson, Director, Utility Services
Clemson University
Brian Mueller, Sodexho Marriott Services
Fred Robson, KraftWork Services Inc.

Three $1,000 Beginning Engineer Fellowships Available

IGTI will provide three travel awards of $1,000 each for beginning engineers who are presenting papers approved by the IGTI Review Chair for publication at ASME TURBO EXPO 2001.

To be eligible for an award, a candidate must send an application letter to:

Beginning Engineer Fellowship Program
c/o Kathy Hawken
International Gas Turbine Institute
5775-B Glenridge Dr., Suite 370
Atlanta, GA 30328-5380 USA

The application letter should state that each of the following items is relevant:

- The applicant must be the author or a co-author — and must be the presenter — of a paper that has been accepted for presentation at ASME TURBO EXPO 2001. **Applicant should enclose a copy of the paper abstract.**
- The applicant must be beginning his/her gas turbine engineering career. The criterion for this can be a point of discussion in the letter.
- The applicant must clearly state that organizational funds to attend the Congress are not available.

Any other pertinent information that the applicant cares to include (briefly stated) will be considered. Brevity is encouraged and the letter should not exceed two pages. The award committee consists of members of the IGTI Board of Directors.

The application letter and abstract should be mailed to arrive at the Atlanta office no later than March 1, 2001. The award winners will be notified as soon as possible after that date. The checks for $1,000 will be presented on-site at ASME TURBO EXPO 2001 in New Orleans, Louisiana.

ASME TURBO EXPO LAND, SEA & AIR 2001

Distinguished Panel to Discuss Aircraft Gas Turbine Maintenance & Repair

The person with engineering responsibility for all U.S. Air Force engines in development, acquisition and operation will chair a world-class panel at TE'01 to discuss and debate current engine maintenance practices, continuing improvements, and the expected advanced technology enhancements for future engines. Otha Davenport, Senior Executive Service, Director of Engineering for the United States Air Force (USAF) Propulsion Product Group, Wright-Patterson Air Force Base, Ohio will fill this role.

The panel of world technology leaders will include gas turbine manufacturers, commercial airline users, and military users. 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, a key ingredient for competitive maintenance, will be discussed with the objective of minimizing the engine operational flight hour cost. Trending, diagnostics, and prognostics also will be presented along with discussions centered on maintaining aging engine systems. No one interested in aircraft engines can afford to miss this panel discussion!

Panelists–21st Century Aircraft Gas Turbine Maintenance & Repair

Otha Davenport, SES, Session Chair
Director of Engineering, Propulsion Product Group
United States Air Force
Wright-Patterson Air Force Base, Ohio.

Jason Chamberlain
Director, Pratt and Whitney Engineering
East Hartford, CT

Scott Crislip
General Manager, General Electric
Evendale, OH

Ron Cherry
Director of Engine Maintenance, Delta Airlines
Atlanta, GA

Jim Uhl
General Manager, Power Plant Engineering, United Airlines
San Francisco, CA

Dave Pauling, SES
Head of Propulsion and Power Engineering, U.S. Navy (NAVAIR)
Patuxent River, MD

TE'01 and IJPGC Welcome Participating Organizations

Three important gas turbine and power generation user organizations, and a Pacific Rim engineering society, will participate with TE'01 and IJPGC in their world-renowned conferences this June. ASME TURBO EXPO—Land, Sea & Air and the International Joint Power Generation Conference, co-locating in New Orleans 4-7 June 2001, are pleased to welcome the following participating organizations:

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

Each of these organizations will be promoting this exciting co-located event to its members and most will be having a booth in the three-day Exposition. The World Energy Council is represented by its Committee on Performance of Generating Plant. The committee will be organizing a panel session and also having its own meeting while in New Orleans. Its booth in the Exposition will have information available on the WEC meeting next year in Buenos Aires. The Gulf Coast Power Association's booth will serve as a rendezvous point for its members and have information available for those wishing to join. The members of the very successful ASME Gas Turbine Technical Chapter in Houston will be available in their booth to offer information and advice to those who may wish to start a Gas Turbine Technical Chapter. JSME will be contributing papers to the IJPGC technical program.

While at TURBO EXPO, take time to visit with these folks and say hello. ✲

World Energy Council GCPA Gulf Coast Power Association JSME

Gas Turbine Certification ... An Update

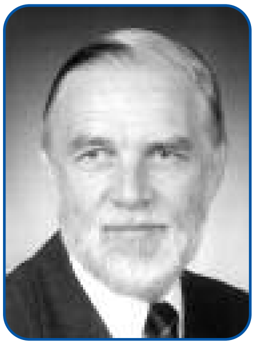
by Lee S. Langston

During 1999 and 2000, in various forums sponsored by IGTI, gas turbine users have complained about the performance of some of the newer, larger (greater than 50 MW) electric power gas turbines, as they enter service. Reports by gas turbine users, buyers, insurers and financiers concern problems with some new machines … problems that range from ones the industry solved decades ago (rotor vibrations, and inadequate through-bolt assembly procedures) to others which might have been solved before going to market (some recent humming combination instabilities, and combustion parts that fail during operation to cause damage to downstream gas path turbine parts). Much to their dismay, users have concluded that extended commissioning periods, performance shortfalls and outages for component repair or replacement have become all too common with the newest models of some large gas turbines.

Last May, two sessions at TURBO EXPO '00 in Munich were held to address these issues through the use of some sort of certification process. A worldwide certification process has long been established for civil aviation gas turbines. In the United States, the third party civil aviation certifier is the Federal Aviation Administration (FAA), and in Europe it is the Joint Aviation Administration (JAA). Both of these agencies require proof by test for gas turbine certification.

One Munich certification session, "Open Forum on Standardization and Conformity Assessment Needs for Gas Turbines", was chaired by Donald Frikken, ASME Vice President of the Council on Codes and Standards. The other, "Future Gas Turbine Certification for Land and Marine Applications", was a panel session organized by Michael Osborne, and Robin Parry, Chair and Vice Chair of IGTI's Marine Committee.

A number of proposals came out of these two Munich sessions. A summary report on the sessions has been posted by Codes and Standards staff member Steve Weinman on the ASME web site http://www.asme.org/cns/departments/Standardization/Public/TuboExpo.html.



Lee S. Langston

Proposals from the two sessions include the following:

- More specific specifications are needed to determine what gas turbine testing is required for certification. These specifications should also include criteria that make it clear when a new gas turbine model is ready for performance testing.
- Along with criteria for comparative testing of new gas turbines, guidelines are needed to determine individuals qualified to carry out the testing.
- To protect a potential gas turbine buyer or user, criteria are needed to define the stage of development of a new gas turbine model or design.
- There is a need for the certification of combined cycle power plant operators.
- There is a need for the certification of gas turbine maintenance organizations.

The proposals resulting from the two Munich TE'00 sessions have been referred to ASME Codes and Standards committees, PTC 22 and B133, both of which deal with gas turbine issues. It will be the job of these committees to incorporate the Munich proposals into existing codes and procedures wherever that is possible and where it makes sense to do so.

As a result of these two sessions it is my opinion that to go further in a land based gas turbine certification process—such as rigorous proof by test required in the civil aviation FAA/JAA program—users themselves will have to form some sort of coalition. User power in the marketplace is needed to push for proof by test certification of electric power gas turbines. ASME Codes and Standards can serve as a focus for standardization efforts, but a rigorous certification of proof by test can most likely come about through the actions of knowledgeable volunteers who have a common interest—and control of the gas turbine marketplace—to make it happen.

> ***"User power in the marketplace is needed to push for proof by test certification of electric power gas turbines."***

A Great Gift for the Holidays–

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 Unites 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 compre-hensive 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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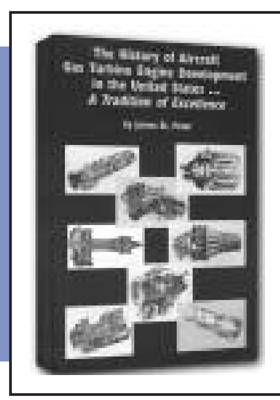
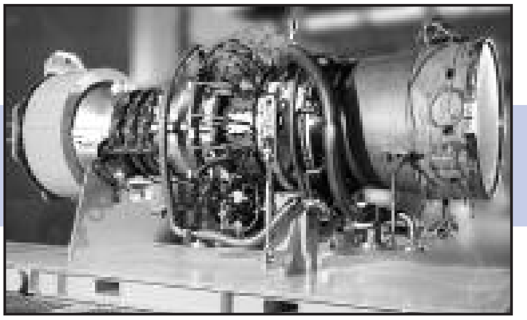


Distributed Power Generation in Europe

by Marco Pucci, Special Project Manager, GEPS Nuovo Pignone, Italy



New GE5 Gas Turbine (6 MW range) suitable for small cogeneration plants.

Distributed power generation, from small production units of a few to some hundred kW (equipped with micro turbines and fuel cells mainly for domestic applications), to larger plants in the range of some MWs (principally for civil and industrial cogeneration) is receiving ever increasing attention. However, situations and trends are very different throughout the world due to a number of historical, economic, social and political reasons.

In the United States for example, more than twenty companies are expected to commercialize these small production plants using micro turbines, fuel cells and advanced reciprocating engines, with a number of joint ventures and strategic alliances ready to respond to market requirements in the next few years. The European scenario seems different and less active in this area, probably due to the present socioeconomic conditions.

An analysis of the European situation is complicated also by substantial differences in political decisions from country to country. However, there are some characteristics that can help us to understand the present European situation better.

Europe has a greater density of population than the United States, with large and widespread electric distribution systems. And most countries have very large public power production companies, practically constituting State monopolies. This situation is now changing and the new password for European governments is "privatize."

In Italy, for example, there is an ongoing program to transfer production capability from ENEL, the national electric utility, to a number of different players, national and international, in order to create a competitive market in electricity supply. This new competitive market also will include a downsized, but privatized, ENEL. The typical attitude of these new players, and of ENEL itself, is to ask for new high capacity combined cycle plants (1.5-2 GW/year for the next 3-5 years) to recover efficiency in energy production. This they consider to be the best way to be competitive in the new market.

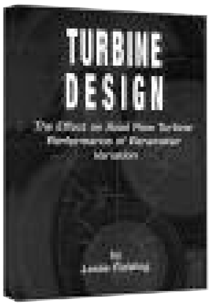
With this kind of scenario, substantial developments in distributed power generation in Europe might seem somewhat unlikely. However, before drawing a final conclusion, it seems worthwhile to consider also the global environmental impact of all activities related to energy production. The 1993 World Energy Council Commission stressed the urgent need for a change in the way the world provides and uses energy in order to be able to meet future challenges successfully. The first years of 2000 were considered to be a key period of transition. To this end, a significant majority of European nations signed the Kyoto Protocol of the United Nations' Framework Convention on Climate Change. In this Protocol, the governments are committed to a "Quantified Emission Limit" with no increase in greenhouse gases by the year 2012 with respect to a base year.

Then, considering not only the adoption of the concepts of "liberalization" and "privatization" in the power generation industry, but also the requirements of significant deployment of energy saving measures under the Kyoto Protocol, we can reasonably expect a significant increase in distributed power generation and cogeneration in Europe in the medium term.

In my opinion the future of distributed power generation in Europe is directly connected with the recovery of the "cogeneration concept." The most important barrier to distributed cogeneration development, particularly for small size plants, is not a lack of appropriate technology. There is an increasing availability of new technology components like micro turbines, small high-efficiency gas turbines, fuel cells, and well consolidated recovery system designs. Instead, the major obstacles are economic and political. These are manifested in an absence of political initiatives, complex bureaucratic procedures and incorrect pricing formulae for combined heat and power production. As a consequence, efficient uses of conventional primary energy resources and reduced environmental impact in terms of emissions, greenhouse effects and the need for new high voltage lines, are not appropriately encouraged or rewarded.

In the future, to take advantage of the potential created by Europe's commitment to sustainable energy development, strategies will require the development of new synergies between market forces and government actions. This would leverage the advantages offered by distributed energy production and cogeneration and lead to the optimum use of energy resources.

"... the future of distributed power generation in Europe is directly connected with the recovery of the 'cogeneration concept.'"



TURBINE DESIGN: THE EFFECT ON AXIAL FLOW TURBINE PERFORMANCE OF PARAMETER VARIATION

by Leslie Fielding

A reference on both aircraft and industrial turbines, this volume details specific methods for optimization and design. A rotary machinery consultant and design engineer, the author examines how to investigate and fix the initial scantling selections for input to analysis or CFD computer programs. He presents a method of selecting the best compromise turbine design, taking into account a range of parameters, including size, stress, and number of stages.

Fielding's method enables a designer to select the best compromise to ensure performance acceptability. The method uses correlations to investigate both the direct and indirect problems. Although the approach is simple, it has been used to design many optimized turbines from both a thermodynamic and structural point of view.

CONTENTS:

1. Basic Turbine Design
Selection of Parameters; Blade Efficiency and Shaft Efficiency; Work Parameter and Flow Coefficient; Degree of Reaction; Minimum hub/tip Ratio; Minimum Exit Mach Number and Reynolds Number; General Parameters; Effect of Stress on Turbine Efficiency

2. Stage Calculations
Introduction; Profile Loss and Optimum Space/Chord Ratio; Secondary and Leakage Loss Coefficients; Three Dimensional Considerations; State Thermodynamic Calculations

3. Thermodynamics and Blade Shapes
Relating Thermodynamic Calculations to Physical Blade; Efflux Angle Prediction from a Blade Row

4. Design Example
Design and Test of a Single Stage Turbine; Selection of Parameters; Detailed Thermodynamic Design; Comparison of Design Prediction and Test Results

Index & References

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For several years, IGTI has subsidized the annual subscription (by ASME members who specify IGTI (#22) as their "primary" technology) to either the Journal of Turbomachinery (TURBO) OR the Journal of Engineering for Gas Turbines and Power (POWER). Below are noted both the subscription rate and structure change and a simplified way of applying for the subsidy.

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GAS TURBINE PERFORMANCE

by Philip P. Walsh and Paul Fletcher

Providing chapters on topics rarely found in textbooks, this volume covers all aspects of gas turbine performance, including transient performance, starting, windmilling, and analysis of engine test data. It discusses all gas turbine variants, including turbojets, turbofans, turboprops, turboshafts, auxiliary power units, and ramjets. The authors emphasize the importance of dimensionless and other parameter groups in understanding the fundamentals of gas turbine performance. Taking an engine performance viewpoint, it examines component performance and design, providing a comprehensive list of references on detailed component aero-thermal and mechanical design issues.

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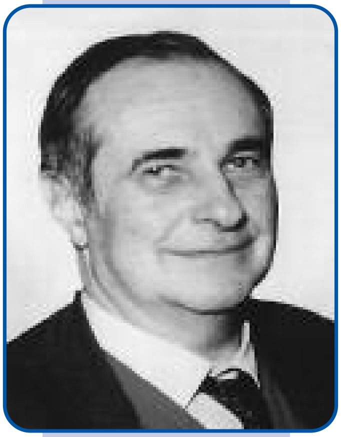
In Memory of Jacques "Jack" Chauvin (1932-2000)

by W. Byron Roberts, Flow Application Research

"Jack" Chauvin, as he was known to his English speaking friends and colleagues, passed on in August from complications of an inoperable brain tumor. He had recently retired as Professor at the University of Marseilles in France and earlier was employed at the Von Karman Institute near Brussels, Belgium.

At each location Jack established or expanded a turbomachinery laboratory for teaching and research. He, his colleagues and students were pioneers in the work on transonic and supersonic compressors, controlled diffusion for compressor blades, and complex boundary layer problems such as laminar bubble prediction for compressor and turbine blades.



Jack Chauvin

Jack will be remembered for his research and innovations; however, his greatest legacy is that of educator and mentor. Thousands of students and, in particular, hundreds of advanced graduate students owe him great thanks for being "their Professor" at the most important time of their careers.

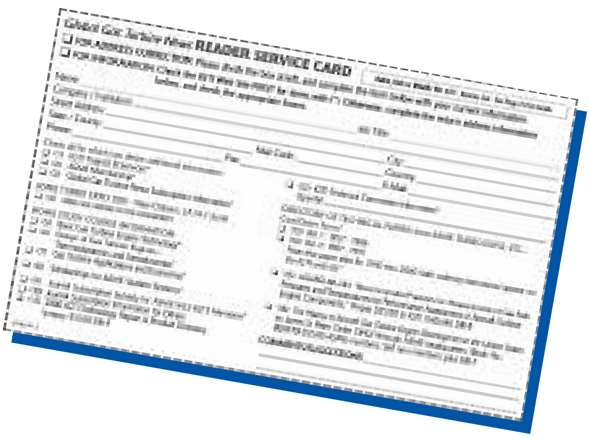
He is survived by his wife Nicole, two daughters: Mireille and Florence, and three granddaughters: Bérénice, Sophiane and Clemence. He leaves also his sister Eliane Chauvin. Our thoughts and prayers are with them.

I will finish this tribute with a paraphrase of my thesis dedication to Jack Chauvin, "The Big Boss ... Although he wasn't always right, he was never wrong!"

NOTICE

Reader Service Card / Address Change

Because extensive detailed information about IGTI is continually updated on the IGTI web site, IGTI has discontinued the inclusion of a Reader Service Card in this newsletter. If you do not have access to the internet, please call the IGTI office in Atlanta at (404) 847-0072 for information requests. Also, continue to send address changes to IGTI to update the IGTI mailing list, even if you are an ASME member and have sent the change to ASME. When sending address changes, be sure to include both the old and the new addresses. New subscriptions to the *Global Gas Turbine News* are available from IGTI for $20.00 per year postage paid for three issues.



Consult the IGTI web site often at: www.asme.org/igti/

GLOBAL Gas Turbine News

Volume 40: 2000, No. 3

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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.

"BASIC GAS TURBINE ENGINE TECHNOLOGY"

Second Edition

> **"This course gives a good general understanding of gas turbines in an easy-to-read format."**
>
> Mark Wolfanger, Engineering Technician, Dresser-Rand/Alfred State College

This home Study Course is a 162 page non-mathematical approach to understanding the fundamental nature of gas turbine engines and the processes which affect their performance. The Course is ideally suited to technicians and management personnel. It will also prove to be of value to those engineers starting their careers in the fields of gas turbine engine and auxiliary equipment operation, maintenance or service, specification, sales and manufacture.

Introduced in 1985, more than 4,000 orders for "Basic Gas Turbine Engine Technology" have been received from industry personnel throughout the world. Here is a sample of comments from some of those completing the course:

"Excellent introductory course that maintains your interest throughout."
William G. Machingo, Staff Engineer. Wright Patterson AFB.

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Timothy A. Trott, Operations Manager, Maghraby Limited.

Course Content

The Course is organized into ten chapters. Following each chapter when you are ready, you will take a test on that material. Take your time in answering the questions and feel free to double check by referring to the text material. When you are satisfied, send the completed tests to the International Gas Turbine Institute in Atlanta for scoring. Your corrected answer sheets will be returned for your information and review. When you have finished the the entire Course, you will receive a Certificate of Completion.

The cost of $145.00 U.S. includes the text, grading and return of exam questions, and issuance of your Certificate of Completion. A special discount price of $95.00 U.S. is available to qualifying students.

"THE DESIGN OF GAS TURBINE ENGINES– Thermodynamics & Aerodynamics"

Second Edition

This Home Study Course introduces you to the fundamental principles for thermodynamic analysis and design of gas turbine components and systems, with insight into design practice. Selected gas turbine hardware is illustrated and described in the accompanying videotape. A companion personal computer program facilitates investigation of the effects of chosen design parameters on performance. This Course is intended for graduate engineers with a knowledge of thermodynamics and an interest in design analysis and performance prediction of gas turbines and components.

Course Content

This 445 page Course consists of 13 chapters and 8 appendices conveniently arranged in one 3-ring binder.

At the end of each chapter is a test that will help you measure your understanding of the content and your ability to work related problems. Test sheets contain multiple choices for ease of scoring by IGTI; however, when your scored answer sheet is returned, it will be accompanied by a detailed solution to each problem and an explanation of answers to other questions.

THE VIDEOTAPE: The two-hour videotape in for VHS cassette players and is available in either NTSC (U.S.) or PAL (European) format. When ordering, be certain to specify which format you require.

THE COMPUTER PROGRAMS: With this Course you receive software programs with which you can calculate the performance of both simple and fairly complex cycles. Programs may be run on most IBM or IBM compatible equipment. They are designed for immediate use and do not require a compiler or a math coprocessor.

The cost of $345.00 U.S. for the Course includes the text, videotape, computer diskette(s), scoring and return of exam questions and answer sheets, and issuance of a Certificate of Completion. A special discount price of $225.00 U.S. is available to qualifying students.

> **"A great course for turbine operators!"**
>
> Arthur Hamilton, Watch Supervisor,Pawtucket Power

"GAS TURBINE APPLICATIONS & ECONOMICS"

If you are involved in the application of gas turbines in such diverse fields as power generation, auxiliary power systems, and cogeneration, or would like to understand more about the design and performance of gas turbine power systems, this course is for you.

Course Content

Performance is the key to application decisions involving gas turbines, and this course begins with a review of the thermodynamic principles for the prediction of performance of several gas turbine types. The involved processes are described, from simple gas turbine cycles, to complex regenerative and cogeneration cycles. Many example calculations are included, and preferred cycles for several different applications are described.

Performance includes economic optimization as well as efficiency, power output, and emissions control; and the course includes an economic optimization method based on an objective equation. Combustion emission laws and methods of compliance are discussed. A computer program, GTSHAFT, on disk is included with the course for the parametric analysis and optimization of gas turbine systems design. The GTSHAFT program includes both the executable files and the source code for convenient student use.

The 228 page Course is divided into nine chapters, and includes discussions of designs and performance calculations, many worked examples, and actual case studies of successful applications. Self-testing exercises, which will be corrected by IGTI, are included.

The cost of $215.00 U.S. includes the text, computer diskette, scoring and return of exam questions, and issuance of a Certificate of Completion. A special discount price of $140.00 U.S. is available to qualifying students.

> **"Excellent review of cycle thermodynamics and performance analysis for engineers involved in unit selection for electric power applications."**
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***Student rate also applies if this home study course is used as part of a for-credit college curriculum.**

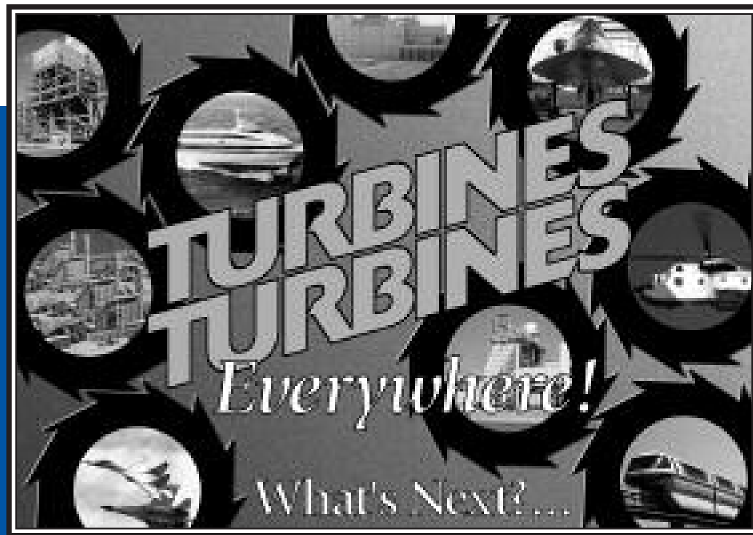
For Tables of Contents, and downloadable Order Form, refer to our web site at http://www.asme.org/igti/

BALLAL RECEIVES AIAA PROPELLANTS AND COMBUSTION AWARD FOR 2000

Dillip R. Ballal

Dilip R. Ballal, Hans von Ohain Distinguished Professor at the University of Dayton, was chosen to receive the American Institute of Aeronautics and Astronautics (AIAA) Propellants and Combustion National Award for 2000. The award citation reads, "for outstanding fundamental contributions to combustion science and jet fuel technology relevant to gas turbine engines." Dilip was presented an engraved bronze medal and a certificate of citation on Tuesday, 18 July 2000 at the 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference held at the Von Braun Civic Center in Huntsville, Alabama.

Dilip Ballal is a Fellow of AIAA and ASME. He is a member of the IGTI Board of Directors and Chair of Conferences for ASME TURBO EXPO '01 in New Orleans, Louisiana next June. ✢



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Color postcards available to send to your friends and colleagues. Remind them to meet you at TURBO EXPO. Call for details: (404) 847-0072 or email: igti@asme.org

IGTI Technical Committees Update Names

Two of IGTI's Technical Committees have received formal approval from the Board of Directors to change their committee's names. The Pipelines & Applications Committee has become the **Oil & Gas Applications Committee**; and the Electric Utilities & Cogeneration Committee has become the **Electric Power Committee**.

Both of these changes were made to better reflect the current scope of committee activities. For details on IGTI's 17 Technical Committees, visit IGTI's web site at www.asme.org/igti/ or email igti@asme.org. ✢

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