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GLOBAL Gas Turbine News

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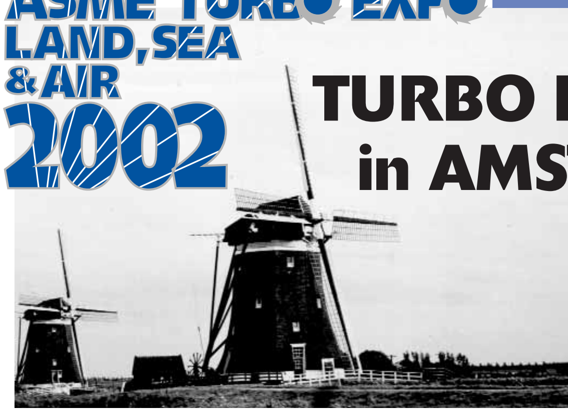
ASME TURBO EXPO LAND, SEA & AIR 2002



TURBO EXPO '02 in AMSTERDAM 3-6 June

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- Large networking session by and for users.
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This year TURBO EXPO, the world's premier educational program for engineers, managers and users of gas turbine technology in all its applications, will again feature its world renowned Technical Congress, a practical Gas Turbine Users Symposium, and a great international Exposition of gas turbine engines, peripheral equipment and industry services. Special articles on pages 12-15 will provide additional details. ✲

IN THIS ISSUE...

TOP KEYNOTERS to SPEAK at TE'02

The Monday morning Keynote Session at TURBO EXPO is open to all TE'02 registrants, regardless of their registration category. This gives all industry visitors and participants at TE'02 an opportunity to hear from industry world leaders. The theme of this year's Keynote is "Gas Turbines for a Better Tomorrow." The distinguished Keynote Speakers are:

Peter F. Hartman, Managing Director & Chief Operations Officer of KLM

Ludo M. J. van Halderen, Chief Executive Officer of NUON, the leading Dutch energy and water company

Nick Salmon, Executive Vice President of ALSTOM

Special welcoming comments will be given by an official government representatve from The Netherlands and by ASME President William A. Weiblen. ✲

Openness and Balance

Dave Wisler
Chair
IGTI Board of Directors

IGTI membership is very broad-based, with constituents from universities, industry, research labs, government, small companies and individual contributors. Many issues are important to this constituency including the quality of the technical papers, cost of the TURBO EXPO conference, location of the conference, quality and relevance of the exhibition, educational opportunities, and the quality of opportunities to interact with associates, vendors, customers and suppliers. The complexity is that the committees, and sometimes individuals within committees, have their own interests and concerns relative to these issues which they promote in major or minor ways. The difficulty for your Board is to keep well informed about committees' and members' interests so that appropriate decisions can be made.

To that end, your Board of Directors has undertaken three new initiatives: (1) publicizing open Board meetings, (2) achieving balance in Board membership, and (3) restructuring the Leadership Workshop. These are described below.

1 Open Board Meetings:

It comes as a surprise to most IGTI members that their Board of Directors' meetings are open to the public, except for relatively short executive sessions. I, too, was surprised when I first learned this.

As Board Chair, I have taken steps to broadcast and capitalize on this "openness." For our August meeting, I invited a dozen "thought leaders" not only to attend but also to participate in the meeting. Admittedly, there was some skepticism, accompanied by concerns that this would be disruptive and unproductive. It turned out quite the opposite. In reality it was immensely productive. We addressed many important issues, such as: strategies for TURBO EXPO, pros and cons of potential alliances and joint ventures, opportunities for new initiatives including a second event, and a discussion of awards, honors, scholarships and other programs. The thought leaders summarized the current thinking of their committees; challenged the Board to address Board-Committee communication, conference business strategies and increasing aircraft engine user participation at TURBO EXPO; and offered feedback to the proposed session organization for Amsterdam. Item #3 of this report, "Restructuring the Leadership Workshop," is a direct result of this dialogue. We will be continuing this policy of meeting openness for the foreseeable future.

If you would like to attend a Board Meeting, please feel free to contact the IGTI office for a meeting schedule and tell the office if you plan to attend.

2 Balance in Board Membership:

Your Board has formally adopted measures to ensure a balance in its membership that is consistent with IGTI makeup. There are two main constituencies of IGTI for which parity is important; namely, the base committees and the applications committees. They each have different goals and agendas. The base committees, or advanced technology committees, are responsible for creating forums that bring together the world's best researchers and engineers to exchange ideas and findings on the leading edge of technology. Historically they have been driven by the aero engine industry with committee participation coming from a broadly based constituency of industry, university and government personnel. Examples of base committees include Turbomachinery, Structures and Dynamics, Heat Transfer, and Combustion & Fuels, to name a few.

The applications committees and the GTUS Advisory Group are responsible for creating forums that deal with the very complex and often frustrating issues of keeping the gas turbine machines running to create power in its multiplicity of forms. They are generally driven by operational and field problems, maintenance and repair issues, training of personnel and government regulations. Examples of the applications committees include Aircraft Engine, Electric Power, Industrial & Cogeneration, Marine, and Oil & Gas Applications.

For the health of IGTI, parity on the Board must exist between the base and applications committees so that both can flourish. In addition, the "agenda field" of each Board member must be sensitive to the needs of both types of committees.

3 Restructuring the Leadership Workshop:

Just prior to opening of each TURBO EXPO and Congress, there is a Leadership Workshop held on Sunday afternoon. Traditionally, this workshop is organized and run by the first-year Board member, with the participation of the other Board members. All Committee Chairs and Vice-Chairs are invited to attend. Although provocative topics have been discussed at this workshop, the thought leaders (see Item #1) gave strong input to the Board that the communication that takes place appears to the committees as "tablets coming down from the mountain." The thought leaders suggested that the Board reorganize the workshop so that the Committee Chairs would run the meeting, with input going to the Board regarding Committee concerns.

This will be done in Amsterdam; but it means that the Committee Chairs must be pro-active in organizing and leading the Workshop, under the guidance of the incoming Board member.

The Board looks forward to trying this new approach and expects much valuable input from the Committees. Of course, the Board will still provide important input to the Committees at the Workshop.

We hope that the three initiatives described above will result in much improved communication between the Board of Directors and the members it serves. ✲

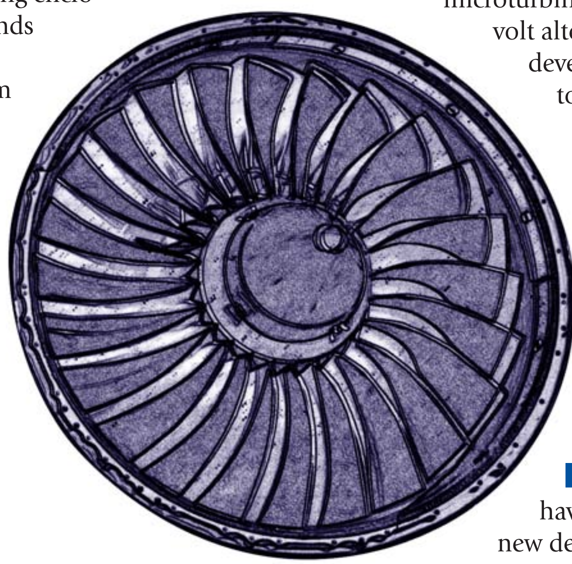
GAS TURBINE NEWS

IN BRIEF

Boeing is preparing to test fuel cells and electric motors for auxiliary power instead of gas turbines. ``Fuel cells show the promise of one day providing efficient, essentially pollution-free electrical power,'' said Dave Daggett, a researcher in Boeing's environmental performance strategy group. ``Our ultimate goal is to replace the auxiliary power unit,'' Daggett said. ``But first, we're going to learn more about fuel cells by powering a small airplane and, as the technology matures, use fuel cells to power an aircraft electrical system.''

Rolls-Royce (RR) released details of its new Marine Trent 30 gas turbine. The gas turbine is to be available for service in either mechanical or electrical genset. The total package, including enclosure and auxiliaries, weighs less than 57,320 pounds (26,000 kg), giving it a market-leading power-to-weight ratio in its class. Available for delivery from late 2003, the Trent 30 has 80-percent commonality with the Trent 800 aeroengine.

General Electric's big new GE90-115 turbofan has reached 120,316 pounds of thrust - the highest ever produced by a thrust gas turbine. The record-setting thrust level was established on November 19 during tests of a GE90-115B development engine at GE Aircraft Engines' outdoor test complex near Peebles, Ohio. The engine reached 120,316 pounds of thrust and then ran at a steady state of 117,446 pounds of thrust.



Pratt & Whitney Canada has enjoyed a successful first run of a complete PW625F turbofan demonstrator, which it regards as the first step in marketing jet engines for the general aviation and super light business aircraft markets. The engine's core is to be scalable down into the 1,000 pound thrust range.

Honeywell/General Electric have reduced the weight of their LV100-5 vehicular gas turbine to the point that it is now 45.5 kilograms (100 pounds) under design weight. In addition, the engine is more fuel efficient than it was a year ago. Honeywell/General Electric are continuing to work on further weight reductions and increased fuel efficiency to power the US Army's Crusader next-generation self-propelled artillery system.

On a related note, the **Army** presently plans to retrofit the LV100 to about 200 M1A2 System Enhancement Package tanks and M1A1 Abrams Integrated Management tanks per year at the Lima Tank Plant beginning in 2004. Another 200 tanks per year will be retrofitted in the field. The Army presently plans to upgrade only 2,845 of its 8,000 tanks over an eight year period, replacing the rest with a next-generation tank.

France's **Snecma** and Russian engine maker **NPO Saturn** are teaming to develop a 12,000-15,000-lb.-thrust-class turbofan for the regional and large business jet market. Designated the SM146, the engine is intended for the markets which are expected to be the most active parts of the air transport business over the next 20 years.

UQM Technologies has received a $100,000 first phase contract from the U.S. Department of Energy to develop a power inverter for distributed power under the Small Business Innovation Research Program. Power electronic inverters are used to convert direct current (DC) output of power generation equipment such as reciprocating engine generators, wind turbines, solar panels, microturbines and fuel cells to 110/220 volt alternating current (AC). The development furthers the move toward the distribution of power generation sources throughout a grid and beyond, fundamentally changing the entire market for providing power.

Catalytica Energy Systems Incorporated and **Solar Turbines Incorporated** have announced the start of a new developmental program that could result in combining Catalytica Energy Systems' Xonon™ Cool Combustion technology with a 5-MW Solar Turbines Taurus™ 60 gas turbine, as part of a $3.0 million grant recently awarded to Solar Turbines by the California Energy Commission (CEC). Xonon is a catalyst-based pollution-prevention system for reducing emissions of oxides of hydrogen.

United Technologies has reorganized its industrial gas turbine businesses under a single organization, **Pratt & Whitney Power Systems (PWPS)**. With this new structure, PWPS can deliver and support the industrial gas turbines built at Pratt & Whitney Canada (250 kW to 4 MW) as well as the FT8 product line (25 - 60 MW) provided by the former Turbo Power and Marine organization. ✻

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*

GAS TURBINE and COMBINED CYCLE DATA COLLECTION and USE

by Bob Richwine, Power Generation Management Consultant
Bjorn Kaupang, Consultant
Sal DellaVilla, Strategic Power Systems, Inc.

INTRODUCTION ...

One of the key conclusions of the recent 18th World Energy Congress held in October, 2001 in Buenos Aires, Argentina was:

> *"If the substantial gap between worldwide average performance and the top performing plants could be eliminated through the application of best practices, this would result in an estimated savings of up to U.S. $80 billion per annum in building and operating capacity and a reduction in CO_2 emissions of one Gt (billion tonnes) per annum as well as a reduction in other pollutants."*

To help in reducing this gap the World Energy Council's (WEC's) Performance of Generating Plant (PGP) Committee has been collecting, summarizing and communicating Performance Data of worldwide fossil steam and nuclear power plants for the past three decades. In addition, the PGP Committee has been conducting workshops and conferences that focus on identifying and sharing industry best practices, especially in the use of historical data to improve future plant performance.

In the late 1980's the Committee recognized that simple cycle Gas Turbines (GT) and gas turbine powered Combined Cycle (CC) power plants were likely to become the technology of choice for new power generation. Therefore, it was decided to begin collecting Performance Data on GT's and CC's in addition to that for fossil steam and nuclear plants. The PGP is currently setting up processes to collect Performance Data on hydroelectric plants plus newer technology "renewables" including wind, photovoltaic, biomass, and geothermal.

GT & CC PERFORMANCE RESULTS TO DATE

Beginning with GT and CC plants from six Pacific Rim countries: Indonesia, Japan, Malaysia, Taiwan, Thailand and Korea, the PGP Committee collected Availability Data and published the results for the years 1991-1993 at the WEC's 16th Congress in Tokyo, Japan in 1995. During the next six years countries and plants were added so that the 2001 report included 691 unit-years of GT data and 1216 unit-years of CC data from 17 countries.

In addition to the original six, the other countries contributing to the database now include Argentina, Egypt, Finland, Hong Kong, Kenya, Mexico, New Zealand, Pakistan, Slovenia, Syria, USA and Venezuela. (Note that only units whose utilization factor was greater than 40% when the unit was available were recommended to be included in the database).

The following Tables give some of the results from the 2001 publication. The complete report can be ordered from the WEC web site at www.worldenergy.org. It will also be available for downloading from the WEC site in March 2002.

The data collection effort for base load gas turbine and combined cycle plants is still under development. For countries with time-based availability data collection systems, unavailability data due to partial outages was requested in addition to the data items shown. The size classes are based on ISO ambient conditions (sea level, 60% relative humidity and a temperature of 15 degrees C). Planned Unavailability (PUF) consists of planned partial and full outages scheduled well in advance. Unscheduled Unavailability (UUF) consists of all unplanned partial and full outages requiring shutdown and repair.

Table 1

Availability Statistics for Gas Turbine Plant
Cumulative for All Years Collected 1991-1999

Size Class MW	Unit Years	Average MW/unit	Availability Percent	Unavailability (%) PUF[1]	UUF[2]	Total
30-75	475	45	80.65	11.54	7.81	19.35
76-150	216	107	86.13	7.08	6.79	13.87
All Sizes	691	64	83.50	9.22	7.28	16.50

1. Planned Unavailability
2. Unscheduled Unavailability

A more detailed analysis (not shown) of the data in Table 1 indicates the rolling three year availability factors for the 30-75 MW group of gas turbines show a definite decline in the three year time periods since the 1991-1993 period, while the 75-150 MW class shows an improving performance over time.

Table 2

Availability Statistics for Combined Cycle Plant
Cumulative for All Years Collected 1991-1999

Size Class MW	Unit Years	Average MW/unit	Availability Percent	Unavailability (%)		
				PUF[1]	UUF[2]	Total
101-200	682	138	84.48	13.55	1.97	15.52
201-300	346	241	84.86	10.99	4.16	15.14
300 & Up	278	404	85.37	8.73	5.90	14.63
All Sizes	1306	222	84.93	10.94	4.13	15.07

[1] Planned Unavailability
[2] Unscheduled Unavailability

A look at the rolling three year availability factors for the combined cycle group (not shown) indicates an improvement and then a falling off of performance in all power classes. As more plants and more countries are added to the database, the causes of this apparent deterioration may be more fully explored.

VALUE OF DATA COLLECTION: RISK VERSES REWARD

Power plant owners increasingly ask "Why should I collect and share my plant's Performance Data when that could potentially hurt my competitive position?" These owners can see very clearly the costs they are incurring to collect accurate data and perhaps believe that sharing that data carries risk (they may not be sure, but why take that chance?). The PGP Committee is aggressively trying to answer their concerns by publishing compelling examples of instances where the value has been clearly demonstrated to be much higher than the cost plus risk. Examples will include case studies from a broad range of industry applications including:

- Equipment Design (incorporating operating data into next generation design).
- Configuration Optimization (trade-off between initial cost and performance value).
- Generation Planning (optimizing reserve margins, etc.).
- Project Development and Financing (helping to prove that the plant will make money).
- Operations (where to focus training, etc. to improve the plant's profits).
- Fuel Quality (is there justification for burning a higher cost, higher quality fuel).
- Maintenance (should I invest in an advanced condition monitoring system).
- Trading and Marketing (what confidence do I have that my plant will be available).
- Risk Management (what hedging options will be cost-effective).
- Life Management (how much am I reducing the economic life of my plant by cycling).
- High Impact-Low Probability (HILP) Event Reduction (reducing catastrophic events).
- Benchmarking and Goal Optimization (how to set optimum economic performance goals).

As a specific example in the area of Generation Planning, a large utility in the U.S. sets their reserve margin based on the point where the marginal cost of additional customer service reliability would equal the marginal value to the customer resulting from a reduction of his Expected Unserved Energy (EUE). Since 90+ percent of the EUE happens during the peak season, the reliability of their generating units during this season was a major contributing factor in determining the optimal reserve margin and the utility's generation plan. In the past the Generating Planning organization had been using an annual average for their unit's reliability. However, studies proved conclusively that the reliability was substantially higher during this peak season, especially for their GT's and other cycling/peaking units. By comparison, base loaded nuclear units' reliabilities were virtually unchanged between the peak and non-peak seasons.

After the Generation Planning Department modified their programs to incorporate seasonal plant reliabilities, the result was a reduction of one full percentage point in the optimal reserve margin. For this large utility, the resulting savings was in the 10's of millions of dollars, while maintaining the optimal economic customer service reliability. In this case no one actually did anything differently or spent any more money (except to do the initial study). But by analyzing the reliability data, they were able to save substantial amounts of money by incorporating into their planning models the higher reliability they were actually achieving during the peak season.

It came as no surprise to the production personnel that the plants were achieving the higher reliabilities, because there were incentives in their goals system to do so. However, no one realized the impact it would have on generation planning and overall savings.

This example is just one that you will soon be able to find on the WEC's website *www.worldenergy.com* at the PGP homepage as part of the PGP Committee's "Study of the Month." The "Study of the Month" will present actual case studies that demonstrate how the value of data collection, analysis and sharing is much greater than the cost.

...continued on page 6

FUTURE APPROACH FOR GT AND CC DATA COLLECTION

The WEC will continue to collect, compile and publish Performance Data for GT's and CC's as well as for fossil steam, nuclear, hydroelectric and renewables. The value is great and will become even greater following the significant structural and technological changes that are taking place in the power generation industry worldwide. Deregulation, global market strategies, and increasing competitive forces are creating significant structural change. Challenging goals for greater output and record efficiency (approaching 60%) with optimized environmental friendliness (NO_x levels at less than 10 ppm on natural gas, and CO_2 sequestration) have motivated technological change and product advancement.

The dynamics of change, however, have created an atmosphere of uncertainty in the market. The uncertainty of meeting demand is exacerbated by the need to have a sustained operating and maintenance process that allows life cycle cost expectations to be met. And while this uncertainty exists, consumer expectations and national interests remain constant ... each demanding a stable, reliable, clean, and affordable supply of electricity. The challenge is to improve the performance of existing generating plants and to build enough new reliable generation and transmission capacity, moving both electricity and the gas supply, to meet growth in demand. Worldwide, 668 Gigawatts of new power generation capacity is planned through the year 2005 with the majority coming from gas turbines in either simple or combined cycle configurations.

Although the level of detail in the current WEC GT and CC data collection process is adequate for general trends to be followed, the PGP Committee believes that it must be enhanced in order for existing and future plants to take full advantage of historical Performance Data. Therefore, the PGP has begun a new initiative to develop an improved data collection program for GT's and CC's, one that will build on the present program but will address future needs. IGTI's Sal DellaVilla is serving as chair of the PGP subcommittee charged with planning for this data collection. The Global Gas Turbine News will keep you informed of further developments. ✲

If you have questions of the authors, or wish to provide feedback, you may contact them by email at:
Bob Richwine … *brichwine43@cs.com*;
Bjorn Kaupang … *bjorn.kaupang@ps.ge.com*;
and Sal DellaVilla … *sal.dellavilla@spsinc.com*.

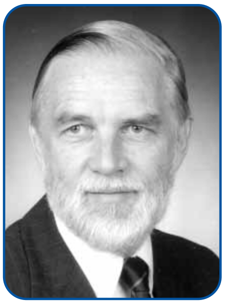
South American Seminar Series a Success at WEC

IGTI's Seminar Series at the October 21-25, 2001 World Energy Congress drew participation from New Delhi to Houston to Yokohama. Topics included "Gas Turbine Project Development Economics," "Overview of Gas Turbine Maintenance and Repair Technology," "Performance of Mature 'F' and Advanced Technologies 2000 Gas Turbines," and "Benefits of Gas Turbine Power Plants."

Speakers included Victor Der, U.S. Dept. of Energy; Ron Natole, Natole Turbine Enterprises; and Septimus van der Linden, ALSTOM Power, Inc. Frederik Bok, Axel von Rappard and Salvatore DellaVilla contributed presentation materials. Sessions averaged 25 persons each. ✲

Sponsors for the series were:
Duke Energy, Bechtel Corp., and ALSTOM Power.

Sep van der Linden (top rt.), IGTI Chair of South American Conferences, welcomes guest speaker Victor Der to the IGTI Seminar Series held in conjunction with the World Energy Congress in Buenos Aires, Argentina. Mr. Der spoke to representatives from around the globe on the latest developments in effective use of gas turbine power plants.



Lee Langston

Gas Turbines and Independent Systems Operators

by Lee S. Langston, University of Connecticut; Editor, ASME Journal of Engineering for Gas Turbines and Power

The deregulation of electric power markets around the world has paradoxically given rise to the creation of new regulatory organizations. These new organizations can now be seen to have the potential of directly affecting electric power gas turbine sales and technology.

In the United States, these new regulatory bodies were brought about by the Federal Energy Regulatory Commission (FERC) as part of the framework to support the deregulation of the $220 billion electric power industry in the 48 contiguous U.S. states. Called Independent Systems Operators, or ISO's for short, their job is to administer the regional electricity wholesale market that determines who will sell generated electric power within the region, and to control the distribution of that power in the regional grid.

Currently there are six ISO's, ranging from ISO New England on the East Coast to Cal-ISO for California on the West Coast. Let us take ISO New England as an example of these six not-for-profit private corporations approved and regulated by FERC since 1997. ISO New England, responsible for the electricity distribution of the six New England states, controls the market for more than 28,000 MW of generation with a staff of about 300 in Holyoke, Massachusetts. Its mission[1] is to:

- Maintain electric power system reliability (keep the lights on).
- Administer the wholesale electricity market place, while ensuring competitiveness and efficiency of the markets.
- Administer transmission tariffs for the regional grid.

Almost all of the new U.S. electric power plants that have been built in the last five years and the many now under construction are gas turbine powered, burning natural gas as a fuel. It can be argued that the ISO administered wholesale market will actually determine which ones will run, based on two factors: 1) their ability to produce power at a competitive price; and 2) their availability.

The competitive price factor is summarized by ISO New England in Fig. 1 and in the following[1]:

"ISO New England is a 'day-ahead-hourly' marketplace. This means that wholesale electricity suppliers and generators will bid their resources into the market the day before and submit separate bids for each resource for each hour of the day.

"ISO New England will tabulate the bids and stack them in dollar terms from lowest to highest matching the expected hourly demand forecast for that hour and each hour in the next day. The ISO Operations staff will then determine the lease cost dispatch sequence for the next day that reflects the actual bids. Generators will then be dispatched to match the actual load occurring on the system.

"The highest bid resource that was dispatched to meet actual load sets the 'market clearing price' for electricity. This is the price [also called the Energy Clearing Price (ECP)] that will be paid to all suppliers by buyers who purchase power from the residual market. The competitiveness of the market is driven by the fact that if a supplier bids [asks] too high a price for its resources, then the unit generator is not dispatched and the supplier receives no revenue. This encourages the supplier to bid the most competitive prices in order to compete for dispatch in the wholesale marketplace."

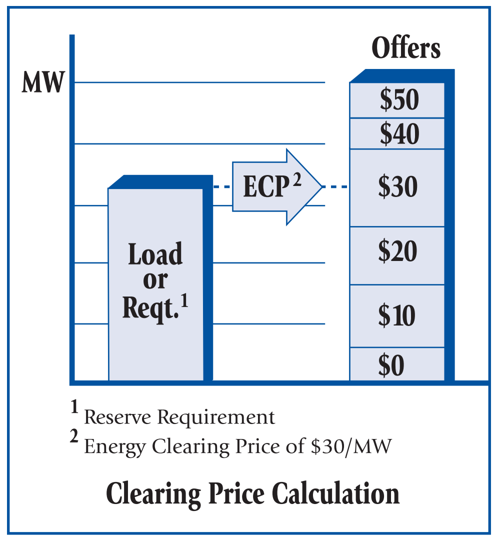


Figure 1
Calculation of Energy Clearing Price (ECP)[1]

The availability factor for the new electric power gas turbine plants is the second important factor. If a generator has proven to have low availability, its bid will most likely be higher than others, so that the market, in effect, will not accept the generator's bid. Recently, ISO New England commissioned a study of the availability of the region's power plants.

...continued on page 8

ISO's ... continued from page 7

The results for 1999 and 2000 are summarized in Table 1[2]. These show that for 2000 the availability for aeroderivitive gas turbine power plants was 88%, simple cycle gas turbines 83%, combined cycle 78%, compared to a system average of 81%. The comparatively low availability value of 63% for 2000 for new combined cycle plants was based on seven new gas turbine-steam turbine units which entered service in 1999 - 2000.

Table 1

Weighted Equivalent Availability Factors (%) by Unit Type, all New England Units

	1999	2000
SYSTEM AVERAGE	**80%**	**81%**
Fossil Steam	79	78
Nuclear Total	82	89
Millstone Point	80	92
Nuclear w/o Millstone	84	87
Jet (aero derivative) Engine	70	88
Combustion Turbine	90	83
Combined Cycle Total	77	78
Pre-1999 combined cycle	91	89
New (installed 1999-2000) combined cycle	32	63
Hydro	81	81
Pumped Storage	90	86
Diesel	76	88
Other	79	91

The low availability of these new gas turbine units is a subject of concern. One could speculate that such unpredictable performance, if not improved, could lead to consideration of gas turbine certification, similar to that used now for aviation gas turbines. The ISO charter of "keeping the lights on" is a matter of public safety, given the extreme importance of electricity to modern everyday life.

Thus the administrative role of ISO's is an important one. As one wholesale electricity supplier put it, ISO's are "in the catbird's seat." Based on bids submitted and electrical power demand, the ISO administered wholesale market determines which generators will run. ISO's have the means to collect data on unit availability and, in order to protect the reliability of the electric power supply, can influence what gas turbine powered units will run. This in turn can influence what gas turbine units might be purchased in the future.

Recently FERC made a proposal to "bundle" ISO's into larger Regional Transmission Organizations (RTO's). As you read this, that suggested reorganization is already underway. In any event, in the U.S.'s deregulated electricity market, one can say that ISO's really have the power over the power. ✻

1. "Overview of ISO New England and NEPOOL", www.iso-ne.com
2. "Understanding New England Generating Unit Availability," June 14,2001, www.iso-ne.com

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Published by the International Gas Turbine Institute

The American Society of Mechanical Engineers

5775-B Glenridge Drive, Suite 370, Atlanta, Georgia 30328-5380 USA

Phone: +1 (404) 847-0072

Fax: +1 (404) 847-0151 or +1 (404) 843-2517

E-Mail: lindsayd@asme.org • Web Site: http://www.asme.org/igti/

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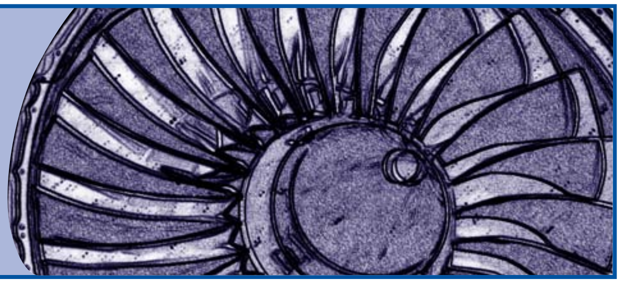


Ted Okiishi

Important News ... from Ted Okiishi, Editor

Valerie Winters, "Production Editor" of the Journal of Turbomachinery since it began in 1986, left ASME last fall. I would like to publicly acknowledge the very high value of her production work and thank her for her years of dedicated and effective service to the journal and its stakeholders. She was absolutely vital to the process of getting the journal into the hands of readers and we will miss her expertise.

For the second consecutive year, papers presented at TURBO EXPO began appearing in print in the October journal issue of the same year and should all be published by the July issue of the following year. These papers are mainly from three technical committees of IGTI, Turbomachinery (18 of 91papers presented recommended for publication in the journal), Heat Transfer (34 of 91) and Structures and Dynamics (33 of 62 presented recommended for publication in either the Journal of Turbomachinery or the Journal of Engineering for Gas Turbines and Power).

These data prompt some discussion. We are currently allocated 850 pages per year by ASME. On average, our papers are about 9 pages long (note that mandatory excess page charges of $200 per excess page over 9 (was 6 until last year) are required of authors) so about 94 papers can be published per year. Most of these are from TURBO EXPO, only 4 papers per year on average are accepted for publication from submissions directly to the journal. Considering that the Structures and Dynamics papers mentioned above are divided between two journals, do the arithmetic and you will see that the backlog problem is no longer an issue. However, fewer papers than we have pages for are being published.

Before we give up our journal pages all too willingly, I ask you to consider the following and let me know what you think by some kind of response (tedo@iastate.edu).

I think most of us are okay with fewer archived papers per year as long as all of the papers presented at TURBO EXPO that are of "permanent interest" are indeed being published. Occasionally, after a paper judged to be of current interest only is presented, more than a few qualified individuals then consider it to be of "permanent interest." In these few instances, a re-review driven by the session chair or the editors of the journal is justified.

Ted H. Okiishi
Associate Dean, College of Engineering
104 Marston Hall, Iowa State University, Ames, IA 50011
Phone: (515) 294-4395, Fax: (515) 294-9273
e-mail: tedo@iastate.edu

TURBO EXPO is still a great venue for presenting new and important technical knowledge about turbomachines to a critical audience of enough size, variety and expertise to make it all worthwhile. The discussions at TURBO EXPO about these papers usually add considerably to the value of these presentations. I would like to encourage more of us to submit written discussions for response by authors and for publication in the journal. This extension of the discussion aspect of our papers by the journal could be a good feature of the journal if we exercise it more often than we currently do.

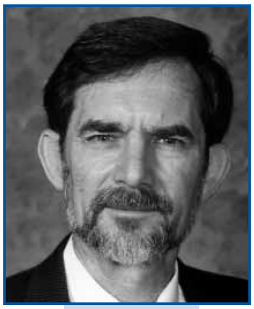
"I would like to encourage more of us to submit written discussions for response by authors and for publication in the journal."

All of the presented papers at TURBO EXPO are reviewed, something that is becoming more and more rare for technical conferences. The IGTI review process in place is one of the most rigorous available, especially when organized correctly. While it is already good, I think we can afford to continue to work on improving the quality of the IGTI paper review process. Any suggestions?

Currently the papers sponsored by the Structures and Dynamics Committee of IGTI are published in either the Journal of Engineering for Gas Turbines and Power or the Journal of Turbomachinery. Should more of them be published in the Journal of Turbomachinery? What do you think?

I look forward to hearing from you. This is your journal, own it. ✻

New Member of IGTI Board of Directors



Harold Simmons Replaces Abbie Layne as Incoming IGTI Board Member

Due to unanticipated business requirements, Abbie Layne, Project Manager with the National Energy Technology Laboratory of the U.S.D.O.E., will be unable to complete her term as Incoming Member of the IGTI Board of Directors. Harold Simmons, Principal Engineer with Southwest Research Institute, will complete her unfilled term. As her job obligations permit, Abbie will attend future Board meetings as a special resource person, and has volunteered to organize a future fall IGTI event. We wish Abbie the very best, and are pleased to welcome Harold to the Board.

Harold Simmons' 38 years as a professional mechanical engineer has been devoted to diagnosing operating dynamics problems in gas turbines, high-performance turbomachinery, and related components. His primary responsibility is to lead troubleshooting projects to solve machinery dynamics problems for clients in the oil & gas, transmission, power generation, pulp and paper, and petrochemical industries. Harold has conducted numerous investigations requiring measurement of cyclic stresses of rotating components to resolve problems of torsional resonance and blading fatigue. He developed instrumentation systems for monitoring critical turbomachines to identify elusive problems involving transient turbine alignment, internal clearances, thermal distortion, flow induced vibration, excessive exhaust noise and coupled torsional/lateral resonances. Prior to joining SwRI in 1974, Harold was employed by Pratt & Whitney Aircraft for 11 years in research, design, and analysis of engines that power the current series of air superiority fighters, the SR-71 Mach 3 reconnaissance aircraft, and liquid fueled rockets. Harold is a Fellow of ASME; Past-Chair of the IGTI Gas Turbine Users Symposium Advisory Group; Past-Chair of the IGTI Controls and Diagnostics Committee; and a Member of the Vibration Institute, the National Society of Professional Engineers and the Texas Professional Engineering Society. Harold has contributed over 45 technical papers on turbomachinery diagnostics, flow-induced vibration, vibration criteria, blade failure detection, and blade clearance monitoring; and is recipient of the 1989 John P. Davis Award from IGTI.

In "real life" Harold enjoys honing his public speaking skills as a member of Toastmasters International, having achieved the level of Certified Toastmaster. He also enjoys sailing catamarans with his son and daughter, and competing in local regattas. Swimming for fitness, traveling and photography are among Harold's other interests, but most of all he enjoys playing with his one and two year old grandsons. ✲

INCOMING MEMBER

HAROLD R. SIMMONS, P. E. -"Harold" (Maureen)
Principal Engineer
Mechanical and Fluids Engineering Division
Southwest Research Institute
San Antonio, Texas USA
Attended: University of Florida
Term: 2001-2002

2001 IGTI Scholarship Recipients

IGTI is pleased to announce the recipients of its $1,000 student scholarships for 2001. Schools with ASME Student Sections are eligible to apply for consideration. Scholarships are awarded to the school and the award recipient is then selected by the members of the ASME Student Section. $20,000 were awarded for 2001. This brings the total amount awarded by IGTI since initiating the Scholarship Program in 1986 to $923,500. Please join us in congratulating the following IGTI scholarship recipients and their schools:

Alfred State University* - Nicholas H. Zwack & Timothy H. Bramer
Arizona State University - Rebecca M. Lewis
Carleton University - Marc Charest
New Mexico State University - Elana Jurado
Northeastern University - Mohamad Khalil
Oregon State University - Thomas Vaeretti
Penn State University - Brian H. Pandya
Purdue University - Robert A. Stines
Syracuse University - Zachary Dineen
University of Alabama - Destin Sandlin
University of Arizona* - Daniel Geyer & Cody Jacob
University of Connecticut - Kathryn Rauss
University of Dayton - Adam Schofield
University of Louisiana - Brandon DeCuir
University of Oklahoma - Julie Marie Schlegel
University of Toronto* - Claudio Barrera & Whitney Taylor
University of Utah - Arthur K. Fox
Virginia Tech - Anna Davis
West Virginia University - John C. Gibble
Wright State University - Jeff Haferd
*Split scholarship – $500 each

Introducing

SELECTED NEW IGTI COMMITTEE CHAIRS

FOR THE 2001-2003 TERM

John has held a wide variety of power generation industry positions involving research and development, power plant operations, project management, engineering/design and quality assurance. His applied skills include distributed control system design and operation, and project management. In 1979, he joined the Electric Power Research Institute (EPRI) where he completed research projects for improving the efficiency of industrial electricity usage. Florida Power Corp. hired John in 1984 to work in power plant engineering and operations/controls in coal fired power plants. John later moved to nearby Orlando, Florida to work for Westinghouse (now Siemens Westinghouse), where he led design teams for gas turbine auxiliary systems and balance of plant equipment/systems. His current assignments include the design of low heating value fueled combustors for gas turbines and related diagnostic instrumentation.

John is a gemologist in his sparse spare time. He enjoys designing and fabricating unique gold and silver jewelry for distribution to family and relatives as gifts. An avid Adobe Photoshop user, he creates digital photographs that have seen publication in digital photography journals. With two children in college and two more in high school, he finds time to sleep once in a while. ✲

COMMITTEE: Coal, Biomass & Alternative Fuels

John S. Brushwood - "John"
Six Sigma Program Manager, G Division
Siemens Westinghouse Power Corp.
Orlando, Florida USA
Attended: University of South Florida
Term: 2001-2003

John (left) with something to smile about ... his drawings returned from drafting without any errors!

Rolf Gabrielsson obtained his MSc in Mechanical Engineering at Chalmers Institute of Technology in 1968. The same year, he was employed by Volvo Flygmotor, where he was leader of the combustor development group. Later he had the same position at ABB Stal. From 1980 to 1990 he was an independent consultant. During this time Rolf also was responsible for combustor development at Volvo Aero Turbine and developed the Volvo Aero "low emission combustor concept" for which he was awarded the Volvo Technology Award for 1996.

From 1990 to the present Rolf has been a Senior Combustion Specialist at Volvo Aero. In 2000 he was appointed adjunct professor at the Dept. of Heat and Power Engineering, Lund University, with a research focus of "Gas Turbine Combustion." He is also chairman of the board of the "Centre of Competence in Combustion Science and Technology, CECOST" at Lund University since 1996.

Rolf enjoys traveling with his wife Berit and is interested in nature and the cultures of different countries. His other passions are fishing and gardening at their summer cottage on the Swedish west coast. ✲

Rolf and Berit enjoying a little summer boating.

COMMITTEE: Vehicular & Small Turbomachines

Rolf Gabrielsson - "Rolf" (Berit)
Senior Combustion specialist
Volvo Aero Corporation
Land and Marine Gas Turbines Division
Trollhättan, Sweden
Attended: Chalmers Institute of Technology
Term: 2001 - 2003

ASME TURBO EXPO LAND, SEA & AIR 2002

The Congress and GTUS

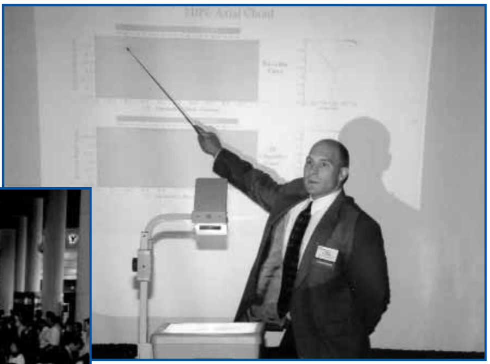
The Technical Congress

Key industry issues to be discussed in Amsterdam will include:

- Distributed Generation – Supplementing / displacing grid supplied power.
- Turbo Fuel Cell hybrid technology.
- Technologies to increase efficiency - automation software, optimization routines for existing applications, better measurement and control devices, and experiences with gas turbine performance enhancement technologies.
- The worldwide engineer shortage.
- Identifying key 21st century technology trends, including advanced gas turbine developments and operating experiences.
- Cost efficient power generation – combined cycle generation.
- And much, much more.

NEW THIS YEAR … there will be **NO PRINTED PAPERS for TURBO EXPO**. All four-day paid registrants for the Congress and GTUS (except complimentary and discounted registrations) will receive a CD-ROM with all 500+ published papers. CD-ROMs also may be purchased separately on-site at TURBO EXPO at a special discounted show price.

Topics for the Congress are selected and organized by IGTI's 17 technical committees and include research into the industry's most perplexing technical issues. Presentations are by world-renowned and up-and-coming authors whose papers have undergone a stringent peer review process before being eligible for non-commercial presentation at TURBO EXPO. ✻



One of the more than 500 presentations of developing gas turbine technology at TURBO EXPO

The GTUS

The Gas Turbine Users Symposium is designed especially for those actively involved with the installation, operation, repair and maintenance of gas turbines in land-based power generation applications. Sessions are organized into three tracks:

- Operations & Maintenance
- Repair Technology
- Engineering & Business

Major panel and discussion topics include: practical aspects of inlet filtration for control of compressor fouling; power augmentation thru inlet cooling; present issues and future direction of dry low emissions; air pollution, hazardous emissions and greenhouse gas prevention opportunities; fuel systems and treatment; long term service agreements; hot section repairs and life extension; and much more. A large networking session by users and for users will provide a forum for open discussion and practical problem solving of issues not covered in the other sessions.

Career building tutorials available include: gas turbine fundamentals and applications; effective technical presentation skills for engineers; gas turbine materials for the non-metallurgist; root cause failure analysis and problem mitigation; practical aspects of cogeneration and combined cycles; combustion and emissions tutorial; and vibration analysis and diagnostics. ✻

GET TURBO-CHARGED … FOR TODAY'S COMPETITIVE ENVIRONMENT

Register today for the TURBO EXPO Technical Congress or the Gas Turbine Users Symposium. Registration and housing forms are available in the Advance Program or on the IGTI Web Site at *www.asme.org/igti/*.

This year's events will feature 176 sessions of which there are 143 in the Technical Congress and 33 in the GTUS. Registration for either of these programs permits access to the sessions of the other.

IGTI Welcomes Participating Organizations

DLR
The German Aerospace Centre

VGT
The Dutch Gas Turbine Association

Three important organizations closely allied with the gas turbine industry will participate with the ASME International Gas Turbine Institute in TURBO EXPO '02. IGTI welcomes The Dutch Gas Turbine Association, The German Aerospace Centre, and The Institute of Mechanical Engineers of the United Kingdom. Each of these organizations will be promoting this important event to its members. ✻

IMechE
The Institute of Mechanical Engineers of the United Kingdom

Other Happenings at TE'02

Special events and activities at TURBO EXPO include:

- Pre-Conference Workshop
- Exposition
- Welcome Reception
- Facility Tours

Pre-Conference Workshop

"Basic Gas Turbine Metallurgy & Repair Technology" is the topic of an all-day User Workshop on Sunday, June 2 sponsored by IGTI's GTUS Advisory Group. A separate registration is required. To register, check the Pre-Conference Workshop box on the TURBO EXPO '02 Registration Form and include the registration fee in your total payment. See page 15 for more information, and refer to the IGTI Web Site (www.asme.org/igti/) for additional details.

Exposition

Make plans to meet with the best minds in the business at the ASME TURBO EXPO Exposition, where you will receive first-hand information … face to face … and hot off the press!

Visit the exhibit hall to see where the "rubber meets the road" with the latest technological advances to propel your gas turbine business into a "better tomorrow." You owe it to yourself and your company to acquire the right knowledge to make the right decisions! The exhibit hall is a great place to network with your peers and discover innovative solutions to your business problems.

Continuing the 3-day format, you'll have plenty of time to meet and network with a variety of the leading gas turbine industry professionals from around the world! Admission to this world-class Exposition of gas turbine products is free to all registered participants and guests at TE'02 Monday thru Wednesday … 3-5 June … in the Hollandhal at the RAI Exposition Centre. Open hours are Monday from noon to 6:00 pm; Tuesday from 11:00 am to 6:00 pm; and Wednesday from 11:00 am to 4:30 pm. Come to TURBO EXPO … and bring a colleague. ✲

Viewing the Exposition

Exhibitor Showcase ! Check out the most current list of exhibitors online at www.asme.org/igti for a continuous list of companies that will be represented. You'll now be able to look at each company's description and category, and link directly to the exhibitor's site to learn more.

Welcome Reception

A Welcome Reception will be held Sunday evening, 2 June, at the world famous Rijksmuseum. The Reception is sponsored by the City of Amsterdam and by Shell Global Solutions International B.V. The Rijksmuseum houses a wonderful collection of international art including "The Night Watch" by Rembrandt. A city official will be present to welcome TE'02 participants. Tickets are required, and will be distributed free-of-charge on-site by IGTI. Safety regulations limit attendance to 750 persons. Ticketing details will be available on the IGTI Web Site.

(courtesy Netherlands Board of Tourism)

"The Night Watch"

Facility Tours

Four facility tours will be available to participants at TURBO EXPO this year. At press time the following descriptions have been received:

- **Amer Power Station** - Facility tour of a plant where a 30 MWe Alsthom/ABB gas turbine has been retrofitted with SwirlFlash overspray injection of hot water. This technology is reported to augment power by 10% and reduce NOx by 40%.
- **Trigeneration Plant RoCa-3** - A visit to what may very well be one of the most environmentally friendly power stations in the world. This 200 MWe plant not only generates electricity, but also supplies heat and CO_2 for greenhouse horticulture.

Further details on these and other facility tours will be made available on the IGTI Web Site as they are received. Tour participation is solely up to the sponsoring facility and is normally very limited. Sign-up takes place in the Exposition during show open hours. ✲

Keep Up-To-Date Automatically
To keep up-to-date on these and other happenings at TURBO EXPO as they are posted, go to the IGTI Web Site and sign up for our "E-Bulletin" … an automatic e-mail update to TURBO EXPO and other IGTI activities.

TO REGISTER for TE'02
go to the IGTI WEB PAGE at … www.asme.org/igti/
or CALL IGTI for a FORM … (404) 847-0072
For Hotel Information, go to the web site also …
REMEMBER, Housing Deadline is March 15 !

Noted Panel to Discuss the Role of Engineering Societies in Developing "Gas Turbines for a Better Tomorrow."

by Dilip Ballal and Riti Singh

Featured panelists for this interactive thought-provoking discussion include engineering society leaders as well as gas turbine and energy industry leaders:

Engineering Society Leaders:

- Sue Skemp, (Pratt & Whitney), President-Elect ASME, New York, NY
- John McDougall, President-Elect IMechE, London, England
- Dr. Yukio Otsuki, Past Chair, Gas Turbine Society of Japan (GTSJ),Senior Technical Advisor, Kawasaki Heavy Industries (KHI), Tokyo, Japan

Gas Turbine and Energy Industry Leaders:

- Phil Ruffles, Director of Engineering and Technology, Rolls-Royce; Derby, England
- Pedro de Sampaio Nunes, Director General of Energy Programs for the European Commission; Brussels, Belgium
- Dr. M. J. Benzakein, General Manager, Advanced Engineering Programs Dept., GE Aircraft Engines

Industry and society leaders will discuss gas turbine education, training and the dissemination of knowledge in developing affordable gas turbines for the 21st century. The industry leaders will discuss issues such as globalization, increasing demand for affordable and environmentally friendly gas turbine products, and the worldwide shortage of gas turbine engineers. Engineering society leaders will discuss the future education and continuing training of gas turbine engineers, the impact of computers and the internet, and cooperation among engineering societies to better disseminate all types of gas turbine educational, research and developmental knowledge. ✲

TURBO EXPO'02 Leadership Team

Ron van den Handel
Executive Conference Chair

The following volunteers will be leading the more than 1,000 individuals contributing their time and efforts to organize and bring to completion what promises to be a highly successful TURBO EXPO '02 in Amsterdam this June 3-6. Our special thanks go to them, to our hard working volunteers at all levels, and to the companies who support their efforts.

Executive Conference Chair
Ron van den Handel
Shell Global Solutions International B.V.

IGTI Chair of Conferences
Ron Natole
Natole Turbine Enterprises, Inc.

IGTI Review Chair
Erio Benvenuti
Nuovo Pignone S.P.A.

Technical Congress Program Chair
Geoff Sheard
Wood Air Movement, Ltd.

Gas Turbine Users Symposium Program Chair
Oscar Backus
Austin Energy

Local Liaison Committee Chair
Andre Mom
Dutch Gas Turbine Association (VGT)

(courtesy Netherlands Board of Tourism)

The Floriade

More Ways to Have Fun in Holland

One of the **special guest tours** available to visitors to TURBO EXPO this year is a trip to the city of Haarlem and the Floriade. Held once every ten years, the Floriade runs from Mid-April to Mid-October, and will play host to over 3 million visitors. Floriade exhibits will cover every aspect of horticulture from bulbs, flowers and plants … to trees, bushes and shrubs … to vegetables and fruits. There will be exhibits and pavilions by landscape gardeners and parks departments, wildlife gardens, hanging gardens, floating gardens and water gardens. International exhibits will include ones from China, the Philippines, Japan, Germany, Belgium, Austria, Luxembourg, North and South America, Africa and Australia. Twenty homes, from a thatched house to a tree house, are being built on four islands in the park area … only a small part of the total 160 acre exhibition.

The Floriade will be a special treat for everyone and not to be missed during your visit to TURBO EXPO. Make your plans now, because the deadline for securing your special TURBO EXPO hotel rates is March 15!

Other proposed guest tours include an Amsterdam Walking Tour, an Amsterdam City Tour (by coach), a trip to the Windmills and Edam, a visit to Volendam and Marken (fishing villages), a Bicycle Tour of the Waterland and Countryside, a trip "In the Footsteps of the VOC" (Dutch United East India Company … founded 400 years ago), and a trip to Delft and The Hague.

IGTI will host a **hospitality suite** each morning, Monday thru Thursday, for spouses and guests to get together for non-scheduled sightseeing and shopping. Details of planned guest tours, including how to sign up and points of departure, will be provided in the TURBO EXPO Advance Program and on the IGTI Web Site at www.asme.org/igti/.

Amsterdam in June is a wonderful place to visit. Bring your spouse or a guest; come early or extend your stay … you'll have a wonderful time. ✲

Basic Gas Turbine Metallurgy AND Repair Technology Workshop

Hosted by the IGTI Gas Turbine Users Symposium (GTUS)

Learn from the Experts!

Operations and Maintenance Personnel Learn ...

- *About gas turbine metallurgy and repair technology!*
- *How to choose replacement parts!*
- *How to do business with gas turbine repair shops!*

Sunday, 2 June, 2002 • 8 am to 5 pm
Amsterdam, The Netherlands

Morning Session:

Typical gas turbine metallurgy, repair processes, coatings and quality control. Accompanying CD-ROM included for use during class and future reference. Bring your laptop.

Afternoon Session:

Case studies covered in an interactive forum. Round table discussions of the latest repair technology trends. Get answers to all your questions.

A unique opportunity to join the experts in

"What you need to know to converse effectively with repair shops."

Registration & Fee:

Separate Fee: Workshop registration is separate from registration for either the TE'02 Technical Congress or the GTUS. Workshop Fee is US$496 + US$94 (Dutch VAT) = US$590.

Form: To advance register for the Workshop, use the TE'02 Advance Registration Form.

3-Ways to Get the Form:
- **WWW:** www.asme.org/igti/
- **Fax:** +1 (404) 847-0151
- **Phone:** +1 (404) 847-0072, ext. 229.

WORKSHOP SPACE IS LIMITED ... REGISTER TODAY!

Go to the IGTI web page for syllabus and latest information.

Morning refreshments, lunch, afternoon refreshments and the course material on CD-ROM included.

Enabling the Turbojet Revolution – The Bramson Report

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

INTRODUCTION

One morning in 1935, a 28 year old British officer, Flt. Lt. Frank Whittle appeared at the consulting offices of M. L. Bramson at Bush House in London. The young Whittle wanted financing for the development of a jet propulsion system for aircraft that he had invented. Bramson was impressed by the enthusiasm and insight of this bright young officer who confidently suggested that aircraft could be powered without propellers or reciprocating engines. Bramson approached the investment firm of O. T. Falk & Partners for funding, but they required a more thorough independent report before deciding. Bramson prepared the report, obtained the necessary funding and Power Jets Limited was born … an event that changed the course of aero propulsion history. This article will examine the background surrounding this momentous event and will describe the important report written in October 1935 that came to be known as the Bramson Report. To put this report and its impact into historical perspective, it is necessary to examine the dynamic of technology change and the difficulties faced by Whittle in proposing his revolutionary engine.

NORMAL AND REVOLUTIONARY TECHNOLOGY CHANGE

The most prevalent technological change is normal (incremental or gradual) change, which consists of innovations that improve the efficacy and efficiency of technology. Development in the turbomachinery arena over the past few decades has been of this nature. Characteristics of normal change include engineering refinements as the result of careful testing and experience, manufacturing process optimization, development of better metallurgy and the development of new variants of existing turbine engine configurations. An example of normal change is the growth in power of reciprocating aircraft engines in the 1925-1945 time frame where power increased tenfold from under 350 HP to over 3,500 HP. This development came at great cost and effort but would still be classified as normal change.

Radical or revolutionary change on the other hand, occurs rarely and involves a step jump in technology. A classic example of such a revolution was the development of turbojet engines, which within a few years, rendered reciprocating aircraft engines obsolete. The turbojet revolution was pioneered by Sir Frank Whittle in England (Figure 1) and Dr. Hans von Ohain in Germany. Both these pioneers, who envisioned flight speeds in excess of 500 mph at altitudes of more than 30,000 feet, had their revolutionary ideas as students, and developed their engines without the help of the traditional aeroengine companies.

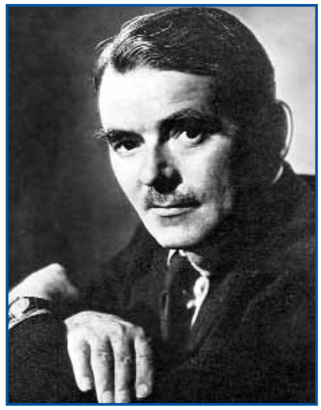


Figure 1: Sir Frank Whittle

Some common attributes of technological revolutions are:

- They occur outside the affected sectors and are often instituted by "outsiders." Turbojet development, for example, was not initiated by any major engine manufacturer but was initiated by "outsiders" … Whittle in England and von Ohain in Germany.
- The "outsiders" are initially opposed or treated with contempt by the ruling establishment who, after the concept is proven and established, embrace it with great enthusiasm.
- Upon establishment of the new technology, control of ongoing developments often passes from the innovator to the more traditional companies.

When Flt. Lt. Frank Whittle first proposed the turbojet concept, opposition and governmental indifference delayed development for years. To compound the institutional challenges and resistance, Whittle also faced significant technical challenges including: developing centrifugal compressor pressure ratios of 4:1 from the prevailing technology level of 2.5:1, increasing compressor efficiencies from 65 to 80%; and designing for combustion intensities that were 10 times the prevailing state of the art in boiler technology.

The Bramson Report presented the benefits of Whittle's engine concept in a remarkably lucid and comprehensive manner, integrating aspects of both the turbojet engine and the type of aircraft that would use this revolutionary powerplant.

Figure 2: The Gloster E.28/39, the first British jet, powered by a Whittle engine.

(Photos and illustrations for this article courtesy of Rolls-Royce)

BRITISH GAS TURBINE DEVELOPMENT

In 1919, when the gas turbine was a developing concept for mechanical drive prime movers, the British Air Ministry asked Dr. W. J. Stern to report on the prospect for the use of gas turbines for aircraft propulsion. His study was flawed in its assumptions and he concluded that the gas turbine was not a feasible proposition. This report was to have an adverse impact on Whittle's quest for support years into the future. Dr. A. A. Griffith, a brilliant scientist who started work at the Royal Aircraft Establishment (RAE) at Farnborough in 1915 and who made fundamental contributions to airfoil theory, was also a gas turbine pioneer. He focused on an exceedingly complex model of an axial flow gas turbine (a turboprop) and could not appreciate the fact that Whittle's centrifugal design had an inherent simplicity that would help promote its success. Griffith played an important part in gas turbine development, but initially rejected Whittle's concept, thereby delaying government assistance at a most critical juncture.

Sir Frank Whittle was born in Coventry on June 1, 1907 and at the age of 16 became an apprentice with the Royal Air Force. Throughout his life, he had a strong sense of curiosity and was a voracious reader, always interested in aircraft and flight. He later became a cadet in the RAF college in Cranwell. At Cranwell Whittle prepared his thesis, laying the groundwork for the turbojet for which he received a patent in 1930. Whittle was hypothesizing speeds of 500 mph and altitudes of 40,000 feet when the best fighters of the time had speeds of 150 mph and ceilings of 10,000 feet. Initially Whittle examined jet propulsion using a ducted fan driven by a conventional engine, but toward the end of 1929, Whittle realized that a gas turbine could be substituted for the piston engine. He performed calculations and discussed the idea with Flying Officer W. E. P. Johnson who introduced the idea to the Air Ministry. This resulted in a meeting between the 22 year old Whittle and the eminent A. A. Griffith, the foremost authority on gas turbines at that time. Griffith did not support the idea but Whittle, urged on by Johnson, filed a patent application.

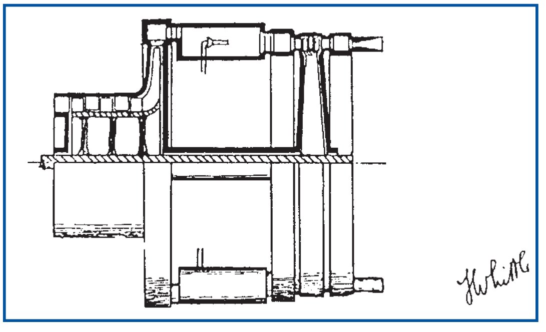


Figure 3: Drawing of Whittle Gas Turbine, British Patent No. 347206.

On January 16, 1930, Whittle filed for Patent No. 347206 for "Improvements in Aircraft Propulsion" (Figure 3). This figure depicts a single shaft turbojet with a two-stage axial compressor followed by a centrifugal compressor, tubular combustor and a two-stage turbine. Between 1934 and 1936, he studied for his Tripos at Cambridge and in 1935, allowed his patent to lapse because the Air Ministry would not pay the £5 renewal fee. Whittle doggedly pursued his goal, and in March 1936 a company called Power Jets Ltd. was launched with a nominal capital of £10,000 and Whittle acting as Chief Engineer. The Bramson Report that is the subject of this article was largely responsible for the formation of Power Jets Ltd.

THE BRAMSON REPORT

In 1935, Whittle approached M. L. Bramson who was a consulting engineer, and a well-known independent aeronautical engineer, and provided him with calculations and thermodynamic studies for a turbojet propulsion system. Bramson was very impressed by this young engineer and after studying Whittle's proposals in detail for two weeks recognized their revolutionary nature. Bramson stated at the end of his study, that "this must be done" (i.e., financed). Having come to this conclusion, he introduced Whittle and his partners to the investment company of O.T. Falk and Co. where Mr. Lancelot I. Whyte decided to proceed with the investment with one proviso - that an independent engineer's report be produced which was conclusive as to the feasibility of the concept. To maintain security, Whittle insisted that Bramson do this independent report. Thus Bramson had to transform himself from his initial role of capital-raising intermediary to an independent reporting engineer. He produced a report that was conclusive and therefore instrumental in obtaining financing of Power Jets Ltd., which then fostered in the turbojet revolution in England.

The report, written in October 1935, entitled "*Report on the Whittle System of Aircraft Propulsion (Theoretical Stage)- October 1935*," was reproduced in the Journal of the Royal Aeronautical Society in February 1979, and its parts are excerpted here by permission. This historic report was important for the following (condensed) reasons as enumerated by Sir Frank Whittle, L. L. Whyte and W. E. P. Johnson:

(1) It was on the basis of Mr. Mogens Louis Bramson's favorable judgment, as Consulting Engineer, formed against much adverse expert opinion, that the development of the jet engine was originally financed and organized …

(2) The Report … is a model of clear and consistent writing and as such deserves to be studied by all technical people whose duties involve reporting. It is remarkable in content, and exemplary in style.

(3) Mr. Bramson has never, in our opinion, received the credit due to him as one of the constructive early proponents: he remained as an actively participating Consultant to the project for several years.

Continued on page 18 …

(4) It has been insufficiently recognized that the Whittle project essentially depended on the marriage of a jet engine with a new subgenus of airframe, and that the boldness and completeness of the total concept (as appreciated by Bramson) went beyond the mere proposal of using a gas turbine to produce a propulsive jet ...

SALIENT CONTENTS OF THE BRAMSON REPORT ...

While space does not allow reproduction of the full Report here, the overall structure is provided below with salient points and excerpts.

TERMS OF REFERENCE

"The purpose of this Report is to record the result of an independent step by step check of the theories, calculations and design proposals originated by Flt. Lt. Whittle, and having for their object the achievement of practical stratospheric transport. No investigation of the patent situation has been attempted."

MATERIALS SUBMITTED BY FLT. LT. WHITTLE

"The inventions and discoveries of Flt. Lt. Whittle have not yet reached the experimental stage, and so the material available for investigation is, necessarily, confined to a reasoned statement of the principles involved, coupled with justifying aerodynamic and thermodynamic calculations and design proposals."

DESCRIPTION

The Problem

This section describes the importance of high-speed flight, the inability of the propeller to function at high altitudes even with supercharging, and the impracticality of previous proposals.

"(Previously proposed jet propulsion concepts) have failed to provide a solution in the main, either because they involved carrying in the aircraft not only the fuel but also the oxygen required for combustion, or because though theoretically capable of functioning in the stratosphere, the means proposed were incapable of raising the aircraft to the stratosphere."

Solution Proposed by Flt. Lt. Whittle

This covers a description of a clean aerodynamic form aircraft with a circular air inlet facing the air stream conducting air to the turbojet and an efflux jet via a propulsion nozzle that provides thrust. The design concept is for a 500 mph aircraft operating at an altitude of 69,000 ft.

Aerodynamic Principles: This section shows that aircraft drag for practical purposes, is inversely proportional to the square root of the air density and that a thrust that would produce say 125 mph at sea level would result in an airspeed of 500 mph at 69,000ft.

Thermodynamic Principles: The basic thermodynamic cycle is presented here, including compression, combustion, expansion through the turbine blades and propulsion nozzle, and return to normal atmospheric pressure. Whittle includes pressure-volume diagrams and entropy diagrams for two sets of conditions: a) 500 mph at 69,000 feet altitude, and b) no airspeed at sea level. Calculations indicate that if the assumed efficiencies of 80% for the compressor and 75% for the turbine are achieved with a pressure ratio of about 4:1, the plane should not only fly, but also demonstrate very rapid acceleration and climb.

Efficiencies: Calculations indicate a thermal efficiency of 48% giving an overall efficiency of 17.13%. Bramson defined thermal efficiency as the kinetic energy given to the working fluid divided by the heat energy input, and overall efficiency as being the thrust horsepower divided by the input of energy in unit time (corresponding to the thermal efficiency of an aeroengine multiplied by the propeller efficiency).

Engineering—The Power Unit: "The Whittle Reaction Engine consists of a single-stage (double-entry) turbo-compressor directly coupled to and driven by a gas turbine of the pure impulse type. Taking the case of a unit capable of a throughput of 2.25 lb of air per second at 69,000 feet, the impeller would be 19 inches and its speed would be 17,850 rpm giving a linear tip speed of 1,470 feet/second." The overall compressor diameter would be 43 inches.

"For efficiency, the linear speed of the single row turbine blades should be one-half that of the gases issuing from the turbine nozzle, which is 2,500 ft/s. The turbine blade speed should therefore be 1,250 ft/s and the effective diameter of the turbine should be 16.15 inches.

"The turbine exhaust gases pass straight to the propulsion nozzle where … the speed of the gases is accelerated to 2,320 ft/s. The volume per lb of gas has at this point expanded to 591 cu ft/lb giving a total of 1,330 cu ft/s in the particular case considered. This gives a propulsion nozzle outlet diameter of 10.25 inches."

Engineering—The Aeroplane: The aircraft as envisioned by Whittle is described here. It would consist of a fuselage of correct streamline form with a sealed compartment for the pilot, passengers and controls. An annular opening of at least 100 sq. in. cross-section would face the air stream. Cabin pressurization would be achieved by using compressor bleed. The wing would be of the cantilever monoplane type with a 52 sq. ft. area and loading of 19.3 lb/sq ft. The plane would weigh about 2,000 lbs.

CRITICAL DISCUSSION

In this section, Bramson checks Whittle's calculations and comments extensively on the following areas: Aerodynamics, Thermodynamics (including compressor efficiency, turbine efficiency, temperature rise due to compressor, turbine blade temperature, and thrust), and Engineering (including the engine, combustion chamber and burners, turbine, weight, and the stratospheric aeroplane design). He then comments on the degree of permissible error in fundamental assumptions regarding compressor and turbine efficiencies.

"The design problems and difficulties to be overcome, in their probable order of importance, (Bramson) summarized as follows:

1. To make provisions for the combined heat and centrifugal stresses at the turbine blade roots.
2. The design and manufacture of a compressor rotor capable of withstanding the centrifugal and bending loads on the vanes.
3. To guard against turbine blade and compressor blade vibration.
4. Design of main shaft to avoid torsional vibration periods, and to resist gyroscopic couples."

Bramson did not regard any of these problems as insurmountable. However, he did not predict the difficulties Whittle would experience with the combustion process.

SUMMARY

Bramson summarized his calculations as corroborating those of Whittle, even considering compressor and turbine efficiency uncertainties.

CONCLUSIONS

Bramson came to the following conclusions:

1. Flt. Lt. Whittle's theoretical calculations and deductions therefrom are substantially correct.
2. His fundamental discovery is that the gas turbine although very inefficient as a prime mover when power is required in the form of shaft horsepower, can be adequately efficient as an auxiliary to the production of a power jet.
3. Should the discovery be successfully put into practice, the points of superiority over existing aeroplanes would be:
   - Economical speeds of 500 mph and over.
   - Probable ranges of 5,000 miles and over.
   - The use of non-volatile fuel.
   - Freedom from noises and vibration.
4. The proposed development, though necessarily speculative as regards time and money required, is so important that it should, if possible, be undertaken.

RECOMMENDATIONS

"The 'Brief Outline of Development Procedure' appended to this Report … has, by request, been prepared by the inventor.

"I recommend the adoption of the procedure therein proposed with the proviso that all designs should be submitted to an independent authority on turbine and compressor design before actual construction is undertaken.

M. L. BRAMSON
8th October, 1935"

Bramson's Findings Bear Fruit …

On May 18, 1935 Whittle filed for Patent No. 459980 for an experimental turbojet, which would be called the W.U. Whittle proceeded to design a double entry compressor with a 19″ diameter made of high strength aluminum alloy and having 30 vanes. The compressor was to be driven by a 16.4″ turbine operating at 17,750 rpm. The mass flow rate was to be 26 lb/sec and the pressure ratio 4.4:1. Whittle recognized that the area of greatest technical risk was in the combustor where an exceedingly large heat release had to be achieved in a very small volume. Whittle's aim was to burn 3.3 gal/min in a volume of 6 cu. ft. After talking to several burner manufacturers, Whittle was able to get the assistance of Laidlaw Drew and Co. to work on a small research contract.

In June 1936, Power Jets awarded British Thomson-Houston Co (BTH) of Rugby a contract for the detailed design and construction of the W.U. Due to severe financial constraints, Whittle could not afford component testing and therefore had to boldly take the risk and attempt to run a complete engine.

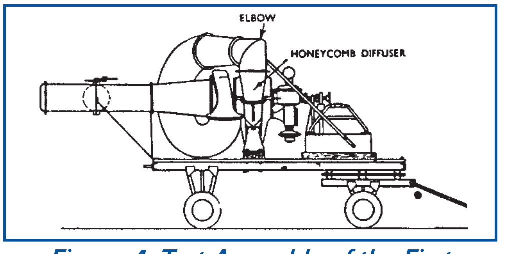


Figure 4: Test Assembly of the First Model of the Experimental Engine.

His initial experiments on combustion were run with very crude combustion test rigs and equipment. Combustion was a major design challenge and the one that Bramson had underestimated. On April 12, 1937, the first runs of the W.U. engine were made (Figure 4). These were eventful because in several instances, the turbine accelerated with a rising shriek to 8,000 rpm even with the fuel valve closed. This uncontrolled and noisy acceleration caused considerable concern as it was usually accompanied by patches of red heat being visible on the combustor, large flames emanating from the jet pipe, and all the operators making a rapid exit from the test cell!

Continued on page 20 …

Finally ...

Finally, it was determined that fuel pump tests conducted prior to engine light-off resulted in an accumulation of fuel in the bottom of the combustion chamber which ignited causing the uncontrolled acceleration. After the W.U., Whittle worked on several engines with the W.1 engine (Figures 5, 6) being used for the first British jet flight.

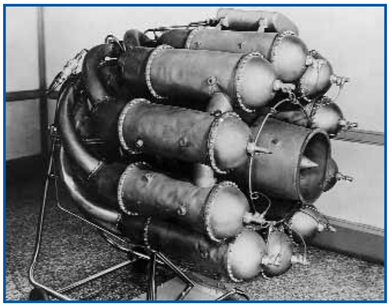


Figure 5: Whittle W.1 Engine

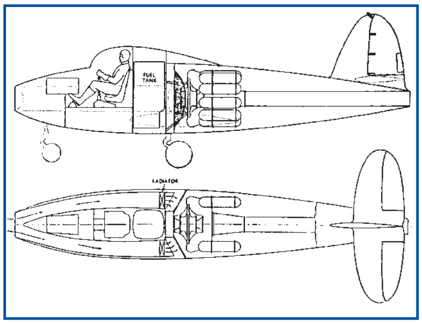


Figure 6: Fuselage of the Experimental E.28/39

On May 15, 1941, the jet age was ushered into the UK with the flight of the Gloster E.28/39, piloted by Flt. Lt. P. E. G. Sayer (Figure 7). Power Jets continued developing engines culminating in the advanced W.2/700 rated at 2,500 lbs thrust. Whittle's theories were proven, and M. L. Bramson's Report was instrumental in that process.

Power Jets Ltd. was nationalized in 1944 and then merged with the aircraft gas turbine section of the Royal Aircraft Establishment to form the National Gas Turbine Establishment. The NTGE was limited to research and to assisting the established aircraft engine industry, which by then, as is typical in most technological revolutions, began to dominate the revolution that it had hitherto resisted.

CLOSURE

As is typical with most technology revolutions, Sir Frank Whittle had to battle not only difficult technical problems but also traditionalists and skeptics who were convinced of the superiority of reciprocating engines. The Bramson Report of October 1935 was a key ingredient in obtaining funding for Power Jets Limited which, in turn, enabled the turbojet revolution. It is interesting to note that all the major western aeroengine manufacturers started their jet engine work based on Whittle's designs. The Rolls-Royce Welland, Derwent, Nene and Tay were based on Whittle designs. Pratt and Whitney entered the gas turbine field after the war using the Rolls-Royce Nene as a basis for its J-42 and J-48 engines. Similarly, General Electric started its jet engine work based on Whittle designs and developed the I-A, J-31 and J-33.

Sir Frank Whittle will always be a beacon of encouragement to engineers not only for his engineering brilliance but also for the tenacious and epic battle he fought against officialdom and entrenched technical opinion to make the jet engine possible. ✲

Figure 7: First Flight of the Gloster E.28/39 on May 15, 1941

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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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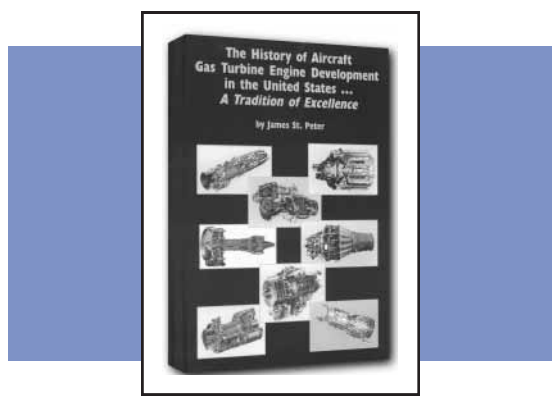

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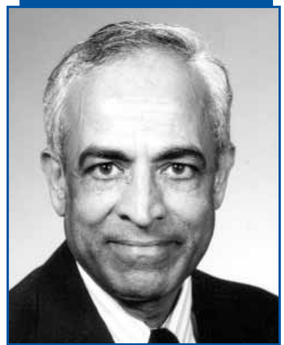
by Robert Kunz



Budugur Lakshminarayana

Budugur "Bud" Lakshminarayana passed away in October in State College, Pennsylvania after a several year battle with cancer. Bud received his doctorate from the University of Liverpool in 1963, having performed his thesis research under Sir John Horlock. He then joined the Aerospace Engineering Department at Penn State University, where his career spanned thirty-seven years. During his career at Penn State, he published extensively in the area of turbomachinery fluid-thermal sciences and was the advisor for twenty-one Ph.D. and twenty-five MS graduate student theses. Bud was instrumental in developing the turbomachinery laboratory at Penn State, which comprised numerous experimental research facilities. He also developed a graduate and research program in computational fluid dynamics. He instructed many undergraduate and graduate courses in the Aerospace Engineering Department and authored a graduate level textbook on turbomachinery.

Bud was an Evan Pugh Professor of Aerospace Engineering, the highest academic rank bestowed on a Penn State faculty member. He was a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and The American Society of Mechanical Engineers (ASME). He was the recipient of numerous professional awards from the Society of Automotive Engineers, ASME, AIAA and the National Science Foundation. He received the Fulbright Senior Professor Award for Research in Germany, and the Distinguished Alumni Professor and Premier Research awards from Penn State. During his career, Bud traveled extensively and was a visiting advisor/professor in Germany, France, India, Japan and the United States.

He had remained active in research, advising and various philanthropic activities. At the time of his death, he was in the process of building an orphanage in Bangalore, India.

Bud is survived by his wife, Saroja Ramanujam; a daughter, Anita Silva of Virginia; a son, Arvind Narayana of Massachusetts; and two grandchildren. ✲

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