Global Gas Turbine News

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In This Issue

ASME International Gas Turbine Institute

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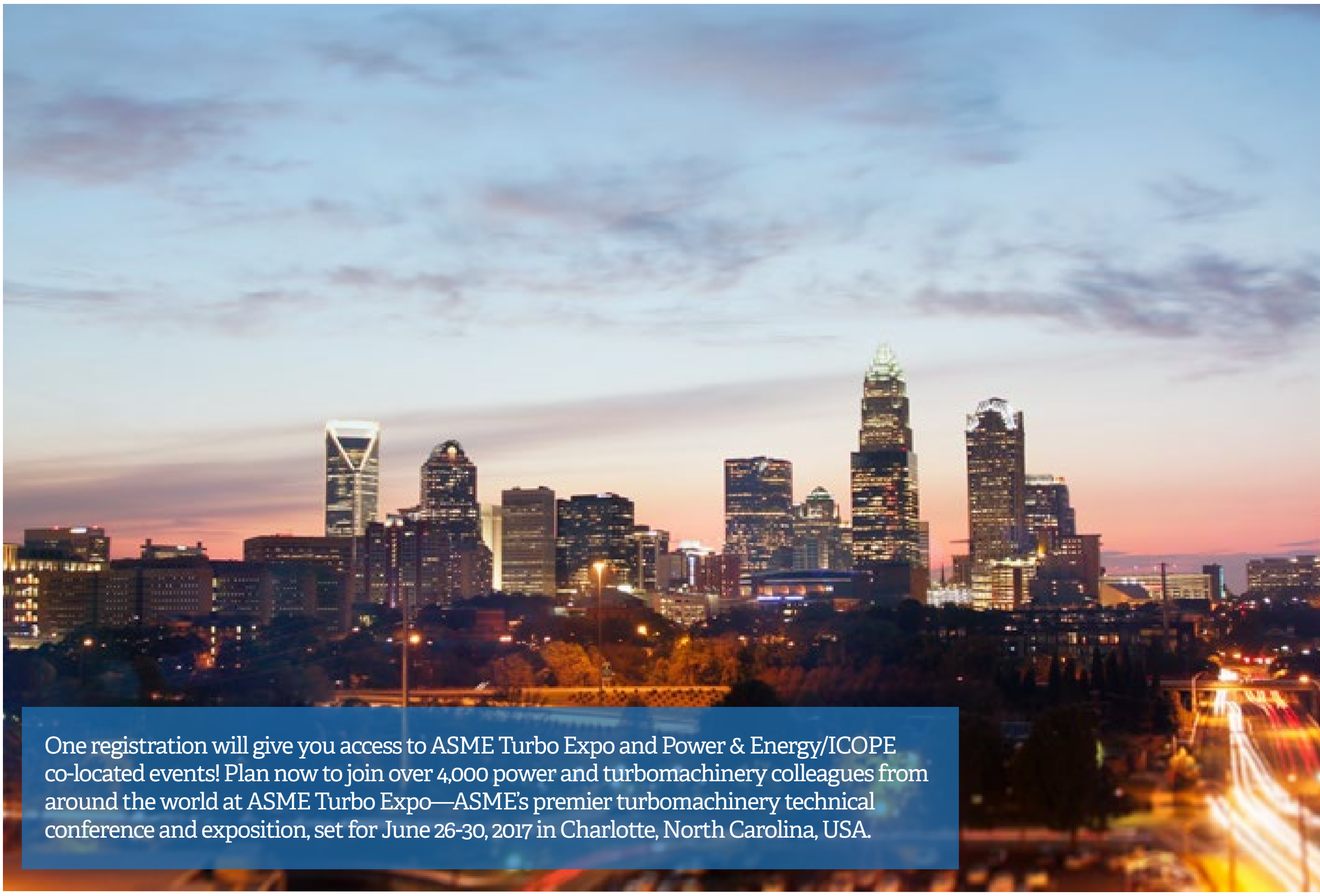


One registration will give you access to ASME Turbo Expo and Power & Energy/ICOPE co-located events! Plan now to join over 4,000 power and turbomachinery colleagues from around the world at ASME Turbo Expo—ASME's premier turbomachinery technical conference and exposition, set for June 26-30, 2017 in Charlotte, North Carolina, USA.

Charlotte

Don't Miss The Big Event. Register Today for ASME Turbo Expo 2017.

Now in its 62nd year,

ASME Turbo Expo is recognized as the must-attend event for turbomachinery professionals. Whether you are a student, professor, engineer, or other industry professional we have something for you.

Networking Events
If you are a woman in turbomachinery, come have dinner on Tuesday night.

If you are a student or early-career engineer, network with your peers at the mixer on Wednesday night.

Join your colleagues for complimentary light refreshments during the welcome reception at the NASCAR Hall of Fame.

The casual atmosphere of these events is ideal to catch up with friends and meet the thinkers from around the world who are shaping the future of turbomachinery and the power industry.

The **advance program** is online, which allows you to look over the technical sessions and decide now which ones you would like to attend. See if there is anything new that sparks your interest—perhaps a new technology that could be of great significance in the future.

For a small additional registration fee, consider attending one of the six **Pre-Conference Workshops.**

Plan now to join 3,000 turbine colleagues from around the world at ASME Turbo Expo, ASME's premier turbine technical conference and exposition!

Turbo Expo 2017, June 26 - 30
Charlotte Convention Center, Charlotte, North Carolina, USA.
For more information, visit https://www.asme.org/events/turbo-expo

Continued on page 58.

NEW at Turbo Expo

AM3D Day

Presented by ASME Gas Turbine

Wednesday, June 28, 2017

Join us at Turbo Expo for AM3D Day! Learn how additive manufacturing (AM) is impacting the gas turbine industry by:

- Enabling new design and material freedoms
- Shortening the development cycle of gas turbines
- Reducing prototype and testing costs
- Producing parts more easily
- Increasing speed-to-market
- Enabling increased performance through novel design

The day will consist of a plenary session from industry leaders, disciplinary panel sessions, specialized exhibits and a student competition.

Additive Manufacturing Plenary Panel Session:
"Disruptive Technologies and Accelerating Innovation in Gas Turbines – The Role of Additive Manufacturing"

Other disciplinary panels will focus on:

- Processes & Materials for Additive Manufacturing
- Design & Performance for Additive Manufacturing
- Challenges and Opportunities in Using AM for Turbine Cooling
- Combustor/Fuel Injector applications for AM

Who should attend?

- Industry experts in gas turbines
- Suppliers/producers of AM machinery
- Suppliers to the gas turbine industry
- QC/QA Technicians
- AM specialists interested in turbine repair
- Industry experts in AM
- Program and Project Managers
- Designers
- Manufacturing Engineers

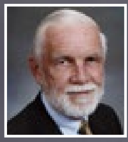
Top 5 reasons to be there:

1. Learn about the state-of-the-art AM methods and gas turbine application
2. Gain knowledge by attending focused panels and sessions on AM
3. Create new synergies and identify new opportunities that benefit both gas turbine and AM industries
4. Network with leading AM experts and companies to understand the potential value propositions for AM in your own industry
5. Support the future of ASME by attending the ASME student competition on AM3D

Don't miss AM3D Day at Turbo Expo, and stay with us throughout the week to visit companies that are showcasing their additive manufacturing technologies on the expo floor.

"As the Turbine Turns...."

#30 May 2017



Lee S. Langston
Professor Emeritus
Mech. Engr. Dept.
University of Connecticut

A Look at APUs - The Power Behind

Airline passengers are generally well aware of the jet engines that provide thrust power for their flight. But out of their sight and usually out of mind, is the smallest onboard jet engine...the aircraft's auxiliary power unit, acronymed as APU.

The APU is typically hidden in a commercial airliner tail cone compartment and isolated from the rest of the aircraft by a firewall. It evidences itself externally by its small exhaust nozzle which opens out in the aircraft tail assembly. All modern passenger aircraft are equipped with an APU, whose main purpose as an onboard gas turbine is to provide secondary power.

Secondary power consists of generator electricity for avionics and cabin systems, hydraulic needs, compressed air for the environmental control system (e.g. cabin air conditioning) and compressed air to power the starter for the aircraft's main engine. (The main engine can then crossbleed to start other engines.) The APU thus enables the aircraft to operate independently of ground support equipment and without the jet engines running.

Most modern APUs can also be started and operated in flight as needed. Their inflight operation is an FAA certification requirement for all ETOPS flights. (These are Extended-range Twin engine Operation Performance Standards for twin-engine jets on routes with specified diversion times to the nearest airport, in the event of an engine failure and the need for single-engine operation.)

APUs, manufactured by companies like Honeywell and United Technologies, come in a range of sizes, depending on individual aircraft needs. For instance, both of the abundant single-aisle Boeing 737s and Airbus A320s have Honeywell APUs, with a shaft power of 447 kW and a dry mass of 145 kg. The current largest APU is in the twin-aisle, double-decked Airbus A380, a Pratt & Whitney Canada APU at 1342 kW and 447 kg. An extensive itemization of passenger aircraft and their APUs is given by Scholz [1].

Usually on-board aircraft batteries are used to power an electric motor to start an APU. Its gas turbine then powers a load compressor (to supply pressurized air (for, say, cabin air and main engine start) and a generator, via a gear box, for electrical power. The APU uses the same fuel as the aircraft's engines, and according to Croft [2], generally accounts for about 2% of the total fuel burn on a typical mission.

Last November at ASME's IMECE in Phoenix, I visited Honeywell Aerospace, where I was hosted by engineers Joe Panovsky and Fred Borns.

Honeywell 131-9 APU

Cutaway Major Features and Airflow Sequence

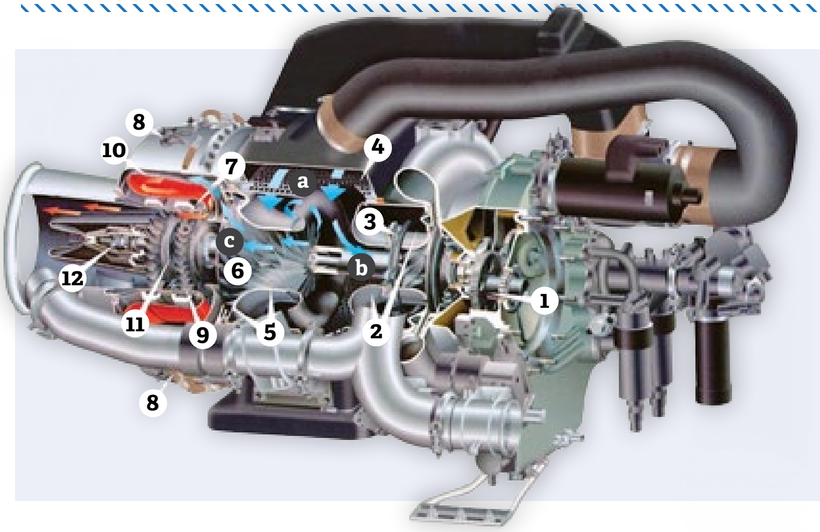


Figure Key

1 Thrust Bearing
2 Load Compressor
3 Inlet guide vane assembly
4 Perforated inlet housing (proprietary inlet design improves performance and acoustics)
5 Engine compressor hub containment
6 High pressure ratio compressor (8:1) for fuel efficiency
7 Cooled first-stage nozzle (improved for longevity)
8 Ten dual-orifice fuel atomizers
9 Full turbine-hub containment for all rotors
10 Effusion-cooled combustor
11 Efficient low-noise, two-stage axial turbine
12 Simple two-bearing, four-wheel rotating group

Air-flow sequence

(a) The air-flow comes in radially through the inlet screen (b) Air is split both ways. To the right is the load compressor that provides the air to the ECS system and starts the main engines (c) The air going left passes through the engine compressor, combustor, and turbine sections (the power section). The power section drives the load compressor and generator.

Figure 1 | Credit - Flight International

Honeywell is the market leader in the APU world, with a current installed base of 35,700 units. They have the APUs (model 131-9, shown in the cutaway in Fig. 1) standard on Boeing 737s and installed in most Airbus A320s. The 131-9 gas turbine is a single spool engine with a centrifugal compressor, a folded combustor and a two-stage axial turbine. This drives a load compressor and an electrical generator through a gear box. My hosts pointed out to me that the unit (Honeywell APU rotor speeds are in the 39,000-63,000 rpm range) will fully contain a turbine-disk failure. (A jet engine company's worst nightmare is an uncontained engine failure, a rare event yet to be successfully prevented [3].)

To get an operant's view, I asked Paul Eschenfelder [4], a retired captain for Delta Air Lines and a U.S. Navy pilot, for his experience with APUs.

He quickly recounted what were the sequence of events for the 2009 US Airways Flight 1549 landing in the Hudson River, after it lost both engines due to bird (geese) ingestion. The first thing the captain did was reach up and hit the APU start button on the Airbus A320. (It had the Honeywell APU shown in Fig. 1.) He also had RAT power (the ram air turbine which drops out of the fuselage for emergency power in the event of a complete engine failure) but the Honeywell APU allowed him to have so much more—more electrical power for radios, instruments and aerodynamic controls.

So despite advances in airplane design, Paul commented that we can view an APU in two lights:

1) It is a device which, on the ground, gives us an environment that passengers demand (cool when hot, hot when cold and electricity throughout).

2) It is a device which may be the back up to the back-ups, but isn't forgotten by the crew, and is viewed as the "ace in the hole" when things get tough.

References

1. Scholz, Dieter, 2015, "An Optional APU for Passenger Aircraft", 5th CEAS Air & Space Conference, CEAS 2015 paper no. 177.

2. Croft, John, 2010, "Power Behind", Flight International, October.

3. Langston, Lee S., 2011, "Gas Turbine Progress through Trouble", Global Gas Turbine News, Mechanical Engineering Magazine, February, p.51.

4. Eschenfelder, Paul 2017, Private Communication, February 13.

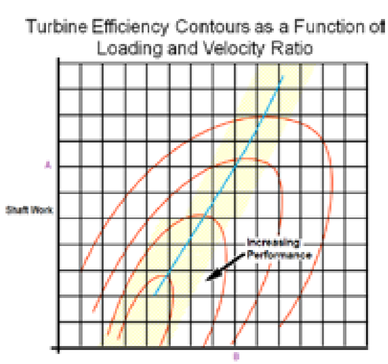
How Many Turbine Stages?

A discussion by Brent A. Gregory (Creative Power Solutions)

Turbine blades all come in the same usual shape with the only seeming variation being varying sizes and either having a rotating shroud or not. However, for similar size Gas Turbines there are sometimes quite dramatic (if not subtle) differences. A good example, that affects the owner/operator directly, is the number of stages in the gas turbine hot section, even though they have similar ratings of MW capacity. Some units produced by various OEM's (Original Equipment Manufacturer) have three (such as GE) stages of turbine, and for a similar output some have four (such as Siemens). Occasionally one might see five stages (as in the case of Alstom). This may be of some cost concern when considering hot gas path replacement or performance-related issues. Other concerns rarely bother the operator, except if clearances or cooling flows are monitored in the form of more performance-related bookkeeping of this particular variable.

The question we wish to ask here is - what determines the designer's choice to select the number of turbine stages for a given design of gas turbine? A reasonable follow up question is who, how or what decides the number of blades in a particular blade row.

Consider this chart:



Looking at the co-ordinates, the shaft work is akin to the "loading" or work performed on the shaft or sometimes by each stage of turbine. The annulus height (a function of the length of the turbine blades), in the case of the Smith chart, is in turn a function of the normalized axial velocity. The chart represents the relationship of the amount of work extracted from the hot gas to that of the blade height (for a given mass flow).

This chart, by Rolls-Royce, shows that the fundamental variables strongly correlate with turbine performance as the independent variable. This can be seen by the red contours in the figure, which illustrate lines of constant efficiency (increasing to the lower left). The highest performance turbines are defined by lower work requirements and slower velocities in the gas path. The fundamental factors determining performance might be relegated to only two factors:

1. Demand on the turbine (shaft work)
2. Axial Velocity (blade height)

It can be seen, therefore, that the blue line represents the peak efficiency line (and hence only one solution) for any given design of turbine.

The chart is significant because:

Given that work is fixed (demand of the compressor and generator [or fan]), and has fixed wheel speed (generally 3,000 rpm or 3,600 rpm for gas turbines in power generation) by the requirement to be synchronous or for aircraft engines the gas generator core speed or the limits of the fan size. Then, since the **work is fixed** (since the work =Mass Flow * Temperature Drop * Cp), the only variables left are the mass flow required to achieve that work and the temperature drop across the turbine.

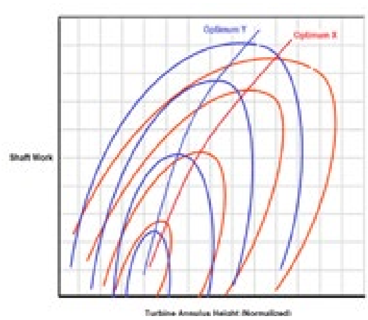
Then the only variable not fixed is the axial through flow velocity (labeled "Turbine Annulus Height") which, from the physics of flow (continuity equation), prescribes the turbine annulus height. This means the designer has few options with which to manipulate a turbine gas path: deviations away from the blue line have a consequence on the blade shape and blade numbers.

Consider an example, the point on the Y-axis at "A" which denotes the required work (given the duty of the compressor and the generator) by the turbine, then the resulting highest performing turbine is prescribed as the point B on the X-axis. Given the annulus area is "fixed" at point B, the designer can fix the maximum diameter, and the annulus area is deduced from simple math (annulus area is a function of the tip and hub diameters).

The maximum diameter is, however, usually chosen at a point where the mechanical designer is comfortable with the maximum stresses on the turbine attachments and the blade length. This is typically the last stage blade.
The aerodynamicist divides the work required on the shaft into several "parts" (where each "part" represents a stage of turbine. If the work A is divided between two stages then the corresponding point on the axis is lowered and the optimum performance curve (the blue line) describes a new point on the Y axis (annulus area). If the work is split among three stages then the points making up the sum of A's value are further lowered and hence also the corresponding points on the X-axis. Note that as the designer invokes this option, each stage of turbine performance increases.

What are the key factors that drive the designer's choice that determine the designer's choice of 2, 3, 4 or even 5 stages of turbine?

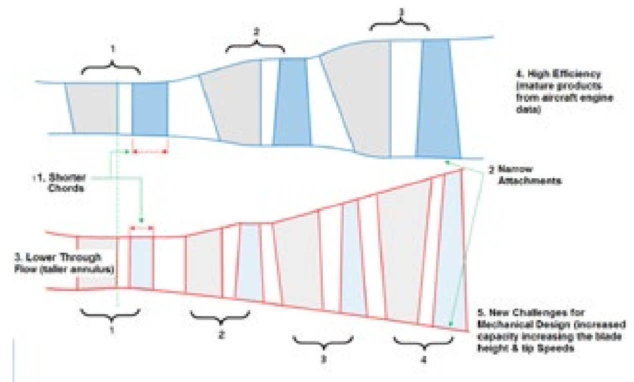
Each OEM then has an optimum set of curves of efficiency, and it is certain they do not line up with one another, consistent with their own particular brand of design. These "brand" characteristics are determined by such things as empiricism derived from previous designs and the results of performance criteria derived from specific tests based on years of research in the academic world and by emerging technologies such as Computational Fluid Dynamics (CFD).



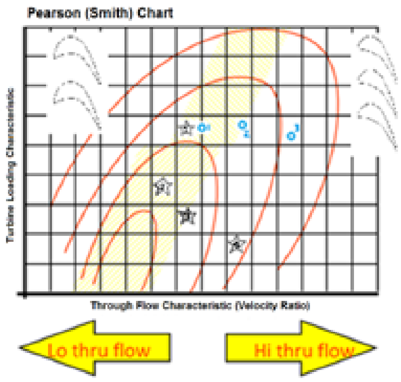
OEM's, typically producing Heavy Frame Gas Turbines (HFGT) together with Aircraft Engines, have a significant advantage when it comes to making technology decisions regarding the components of a Frame Engine, because it increases the range of experience for a given variable—hence, 3-stage designs may even trump the 4-stage design in terms of performance.

Aircraft engine technologies drive new initiatives because of the need to increase firing temperature and dramatically improve efficiency for substantially less weight. Also, the expansion across each stage determined the annulus area so that the optimums implied by the Pearson chart were largely ignored. Developments in aircraft engine gas turbines have forced HFGT OEMS to rethink many historical paradigms.

Below is a typical 3-stage HFGT turbine, and below it is what an equivalent 4 stage would like.



Considered on the Smith chart the stage characteristics for the above turbine schematics are represented in the following chart:



Note the unique features that have forced the OEM's to rethink:

1. Lower "through flow" allows the expansion of each stage to be incorporated in the same diameter as a 3-stage allowing for a retrofit of a 4-stage unit into a similar area.
2. Shorter chords as a result of highly loaded airfoil (more work per blade) technology.
3. Higher loading, reducing airfoil count
4. Attachment areas are refined based on aircraft engine technology.
5. Lower through flow allows for optimized efficiency.
6. Four stage designs do allow for increased performance with larger capacity.

Ref 1. "A Simple Correlation of Turbine Efficiency" S. F. Smith, Journal of Royal Aeronautical Society, Vol 69, July 1965

Ref 2. Improvements to the Ainley-Mathieson Method of Turbine Performance Prediction
J. Dunham and P. M. Came. J. Eng. Gas Turbines Power 92(3), 252-256 (Jul 01, 1970) (5 pages)doi:10.1115/1.3445349

Ref 3. Craig, H. R. M., and Cox, H. J. A., "Performance Estimation of Axial Flow Turbines," Proceedings of the Institution of Mechanical Engineers, Vol. 185, No. 18, pp 407-424, 1971.

"Charlotte" Continued from pg. 52

ASME 2017 Turbo Expo Conference Keynote and Plenary Panel Sessions

MONDAY KEYNOTE: DISRUPTIVE TECHNOLOGIES & ACCELERATING THE PACE OF INNOVATION IN GAS TURBINES

Panelists:

Dag Calafell
Upstream Machinery Chief
Exxon Mobil

Jean-Paul Ebanga
President & CEO
CFM International

Karen B. Florschuetz
President and General Manager
Operations Americas
Dresser Rand, USA and India

Kevin Murray
General Manager, PMC
Engineering & Construction
Duke Energy

Moderators:

Mark Turner
Professor
University of Cincinnati

Paul Garbett
Head of Large Gas Turbine Engineering
Siemens Power & Gas Division

TUESDAY PLENARY: MULTIDISCIPLINARY COMPUTATIONS AND OPTIMIZATION IN GAS TURBINE DESIGN

Panelists:

Dr. Eisaku Ito
Senior General Manager, Business Intelligence & Innovation Department
MHI

Dr. Ingrid Lepot
Research and Technology Manager
Cenaero

Robert Nichols
UAB/AEDC, DOD HPC Modernization Program

Moderators:

Dirk Nuernberger
Siemens Gas Turbines

Mark Turner
Professor
University of Cincinnati

WEDNESDAY PLENARY: DISRUPTIVE TECHNOLOGIES AND ACCELERATING INNOVATION IN GAS TURBINES: THE ROLE OF ADDITIVE MANUFACTURING

Panelists:

Christine Furstoss
Technical Director, Manufacturing, Chemical & Materials Technologies
GE Global Research

Markus Seibold
Power & Gas Business Lead for Additive Manufacturing
Siemens

Mike Aller
The Consortium for Advanced Production & Engineering of Gas Turbines

Rob Gorham
Director of Operations, National Center for Defense Manufacturing and Machining
America Makes

Thomas W. Prete
Vice President, Engineering
Pratt & Whitney

Moderators:

Karen A. Thole
Department Head of Mechanical and Nuclear Engineering, Professor
Pennsylvania State University

Rich Dennis
Advanced Turbines Technology Manager
U.S. Department of Energy National Technology Laboratory

ASME IGTI Awards & Scholarships

2017-2018 IGTI Student Scholarship

The deadline to submit an application is June 15, 2017.

ASME IGTI will provide up to 20 $2,000 (US) scholarships this school year to qualifying students registered at an accredited university (U.S. or international).

2018 Dilip R. Ballal Early Career Award

Nominations for the 2018 award are due to igtiawards@asme.org by August 1, 2017.

Early Career Awards are intended to honor individuals who have outstanding accomplishments during the beginning of their careers. The recipient of the Early Career Award will be presented with the award at Turbo Expo 2018 in Oslo, Norway.

The ASME R. Tom Sawyer Award

The R. Tom Sawyer Award is bestowed on an individual who has made important contributions to advance the purpose of the Gas Turbine Industry and to the International Gas Turbine Institute over a substantial period of time. The contribution may be in any area of institute activity but must be marked by sustained forthright efforts.

Nomination packages should be received at the ASME Office no later than August 15, 2017, to be considered: igtiawards@asme.org.

For more detailed information on these opportunities, please visit: https://community.asme.org/international_gas_turbine_institute_igti/w/wiki/4029.honors-and-awards.aspx.