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GLOBAL GAS TURBINE NEWS

In this Issue...

ASME
Gas Turbine Segment
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ASME Turbo Expo

VIRTUAL EXHIBIT

A virtual trade show just like a physical expo hall: to see innovations and make connections; to grow sales and profitability.

We still need and want to connect with exhibitors who can bring us new products, enhanced services, and solutions to better serve the turbomachinery community. ASME Turbo Expo Virtual gives you a way to still connect.

We plan to have the ASME Turbo Expo Virtual event during the week of June 7-11. A registration allows for participation in the keynote, paper sessions, poster session and discussions. But even beyond the paper sessions that week, we are encouraging the registrants to go online at their convenience 24-7 to check out the exhibition. Just think, every attendee from around the world can now check out your company personally when it's most convenient for them during the Live event and for 90 days after!

So, thank you for considering becoming a virtual exhibitor or sponsor of the ASME Turbo Expo Virtual Conference and Exhibition! We hope to continue our tradition of our annual face to face event in June 2022 in Rotterdam.

We are committed to ensuring that ASME members and the turbomachinery community have access to the latest products and services that will assist in restoring business as quickly, efficiently, and profitably as possible.

Virtual Show Participation Benefits:

- Wider Audience Reach (Geographically)
- Deeper Audience Reach (Positions within the Industry that might not make a face to face event)
- Longer Selling Time with a Week Before, During, and 90 Days After the Event
- Great Branding and Sponsor Opportunities
- Opportunity to Make Connections and have Conversations to Capture New Leads
- Include Videos of your Latest Products, Add Photos and make Comments in Your Show News Feed

The exhibition will be held during the virtual conference, June 7-11, 2021.

Exhibition Information

Book your virtual space now. Branding, visibility, and showcase opportunities available before, during and after the virtual conference. To request to join the virtual exhibition and engage with the global turbomachinery audience, send an email to ***igtiexpo@asme.org*** today.

$1200 Virtual Booth — Load images, videos, presentations, and up to 5 downloadable content documents in your virtual booth. Includes lead generation and one technical conference badge. Attendees can start conversations with exhibitors using email and/or video chat, in a one to one chat or group chat setting. Your logo with a Web link and 15-word description will be on the exhibitor page of the ASME Turbo Expo Virtual Website in addition to the platform virtual booth. During the event, your logo will be visible for attendees to encourage visiting you in the exhibition. After the event, you will be provided a detailed report showing how many people visited, the content that was reviewed, and more.

Become a Virtual Event Sponsor

Just like an in-person event, your sponsorship is the key to gaining visibility, breaking through to reach target customers and prospects, and showing your support for the industry. Now more than ever, your sponsorship makes all the difference! See the below cost-effective marketing opportunities.

Bring prospects to you with sponsorships, branding, and advertising! Become a sponsor today by completing and returning the Sponsorship Form on the Turbo Expo Website: ***www.turboexpo.com***

Platinum Club: $10,000 USD (Limit 3)

- Sponsor booth in exhibition hall
- 4 complimentary virtual event badges
- Company logo in event emails
- Branding on the Turbo Main Stage where all attendees check in
- Opportunity to send a targeted email to registered attendees
- Social media post with logo on social channels by ASME
- Event push notification encouraging attendees to visit your booth
- Logo on ASME Turbo Expo Virtual Event Website
- 20 content pieces available for download in your booth
- Logo on Show Registration/Login page
- Full page ad in the online Advance Program

Gold Club: $7,500 USD (Limit 4)

- Sponsor booth in exhibition hall
- 3 complimentary virtual event badges
- Company logo in event emails
- Opportunity to send a targeted email to registered attendees
- Social media post with logo on social channels by ASME
- Logo on ASME Turbo Expo Virtual Event Website
- 15 content pieces available for download in your booth
- Logo on Show Registration/Login page
- Full page ad in the online Advance Program

Silver Club: $5,000 USD (Limit 5)

- Sponsor booth in exhibition hall
- 3 complimentary virtual event badges
- Company logo in event emails
- Opportunity to send one targeted email to registered attendees
- Social media post with logo on social channels by ASME
- Logo on ASME Turbo Expo Virtual Event Website
- 10 content pieces available for download in your booth
- Logo on Show Registration/Login page
- Half page ad in the online Advance program

Bronze Club: $2,500 USD (Limit 6)

- 2 complimentary virtual event badges
- Company logo in event emails
- Opportunity to send one targeted email to registered attendees
- Social media post with logo on social channels by ASME
- Logo on ASME Turbo Expo Virtual Event Website
- 8 content pieces available for download in your booth
- Logo on Show Registration/Login page
- Half page ad in the online Advance Program

Additional Sponsorship Opportunities

Virtual Networking Break

For great conference visibility, sponsor the conference breaks. Select the day of your choice. You may have a 60-second video presentation loop during the breaks of the day.

$3,000.00 *Limit one daily sponsor.*

Tutorial Sponsor

Opportunity to sponsor the educational tutorials—a 60-second video will play on the tutorials landing page.

$2,000.00 *Limit 1 sponsor.*

Student Poster Competition:

Opportunity to sponsor the student poster competition—a 60-second video will play on the poster landing page.

$750.00 *Limit 1 sponsor.*

Virtual Event Supporter:

For logo placement, join us a virtual event supporter and have your logo on the Turbo Expo Webpage as well as on the Turbo Main Stage during the Virtual event.

$500.00 *Limit six sponsors.*

Women In Turbomachinery Social:

Support the women in the industry. Our first virtual gathering for women will include a speaker and networking. 2-minute video and logo placement from sponsor.

$1500.00 *Limit one sponsor.*

A SUPERCRITICAL CO_2 GAS TURBINE ALERT

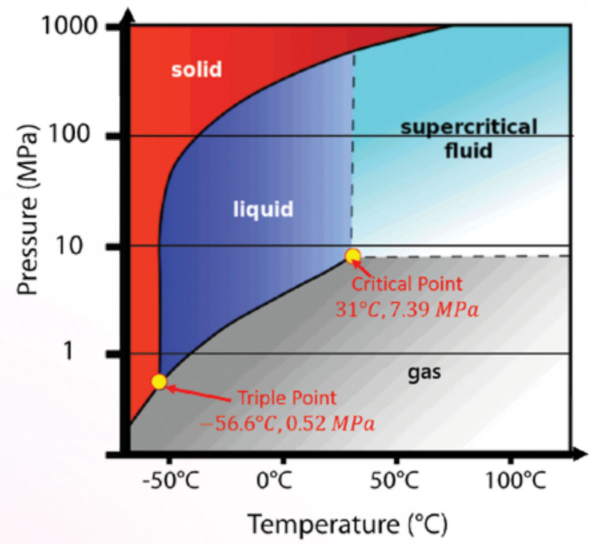
#45 - February 2021

By Lee S. Langston,
Professor Emeritus,
University of Connecticut

There may very well be a supercritical carbon dioxide (sCO_2) gas turbine in your electric power plant future. Supercritical CO_2 is employed in the coffee industry as a decaffeination (depowering?) agent, but if used as a working fluid in a gas turbine, it promises increased power density, reduced compressor work, and increased thermal efficiency at lower turbine temperatures.

The ever-adaptable gas turbine, whose ideal thermodynamic pattern is the Brayton cycle, is currently being studied, tested and developed by various groups and organizations to use sCO_2 as a working fluid in high efficiency, closed cycle configurations. In what follows, we aim to look at sCO_2 features, to review aspects of closed cycle operation and to present the results of one such sCO_2 gas turbine study.

Figure 1. Carbon Dioxide Pressure -Temperature Phase Diagram (adapted from [1]).



Supercritical sCO_2 Highlights

Figure 1 is the temperature-pressure phase diagram for CO_2 [1], showing the triple point where three phases—gas, liquid and solid (dry ice)—exist in equilibrium. Also shown and key to our discussion, is the CO_2 critical point (at 31.0° C (87.8° F), 7.39 MPa (1071 psia) which demarcates supercriticality. At the critical point, CO_2 fluid has a density of 466.7 kg/m^3 (29.14 lbm/ft^3), about half that of water and almost 400 times greater than that of atmospheric air.

As shown in Fig.1, a supercritical fluid is any substance at a temperature and pressure above its critical point (but below the pressure required to compress it into a solid). A supercritical fluid is neither a pure gas nor a pure liquid. As such, its temperature yields molecular kinetic energy high enough to overcome intermolecular forces to condense it to a liquid phase, and its pressure would not allow it to stay in a pure gaseous state. The balance yields its supercritical state with properties between a liquid (higher density) and a gas (compressibility, lower viscosity and the ability to expand to fill a space). Also, important for power conversion devices like a gas turbine, small charges in pressure and/or temperature, can bring about large changes in density (significantly more so than with air).

To create shaft power, an air-breathing gas turbine must compress air, combust the air with fuel, and expand the exhaust for work output, which is accomplished by a compressor, a combustion chamber, and a turbine, respectively. To efficiently compress gaseous air over the range of operating conditions that a gas turbine experiences is not an easy task. Approximately 50-70% of a turbine's power output is used to run the compressor. For comparison, a steam power plant uses only about 1% if its output to power the feedwater pumps that resupply incompressible water to the boiler.

With supercritical CO_2 as the working fluid in a gas turbine, much less compression work is necessary, as a result of its higher density and density changes, compared to air. Thus, compressor work is greatly reduced, to allow more turbine output to go directly into shaft output power, leading to increased engine thermal efficiency.

The high fluid density of sCO_2 as a working fluid results in smaller and compact, higher rpm turbomachinery components. This has led some to report this compactness will lead to lower component costs. Some of us who remember the problems that were had with the very compact, energy dense space shuttle main rocket engine turbopumps, would urge caution on accessing predicted lower cost estimates.

The Closed Cycle Gas Turbine

We first consider a closed cycle gas turbine where the working fluid (air, CO_2, helium, etc.) is recirculating without any internal combustion occurring in the working fluid. (Closed cycle electric power plants, 24 of which were installed from 1940 into the 1980s are treated and reviewed by Frutschi [2].)

Approximating a thermodynamic Brayton cycle, the closed cycle gas turbine has two heat exchangers, one for rejecting heat from working fluid entering the compressor and one for energy addition to flow entering the turbine. The latter is heated by an external energy source such as combustion (no problem here with burning "dirty" fuels), a solar collector or a nuclear reactor.

The chief disadvantage of the closed cycle gas turbine is that the allowable working temperatures of the heated heat exchanger surfaces impose a fairly low upper limit on maximum temperatures in the cycle, keeping achievable cycle thermal efficiencies reported on by Frutschi [2] in the 20-30% range (compared to modern open cycle gas turbine power plants in the 35-60% range.) Also, the heated heat exchanger has to be very large compared to other components, amounting to as much as 40% of the plant capital cost. However, these heat exchanger limitations should not be as serious with sCO_2 as the working fluid, since cycle temperatures will be lower than that with air.

The part load characteristics of a closed cycle gas turbine are remarkably better than those of open cycle operation. In closed cycle operation, load reduction is achieved by bleeding the working fluid from the closed loop. This reduces the mass flow rate, reducing system pressures, lowering working fluid density, and lowering power output, but maintaining constant fluid velocities at constant rpm. In gas turbine designer terminology, the turbomachinery velocity triangles remain the same, so that closed cycle design thermal efficiency will remain the same over a wide range of load operations.

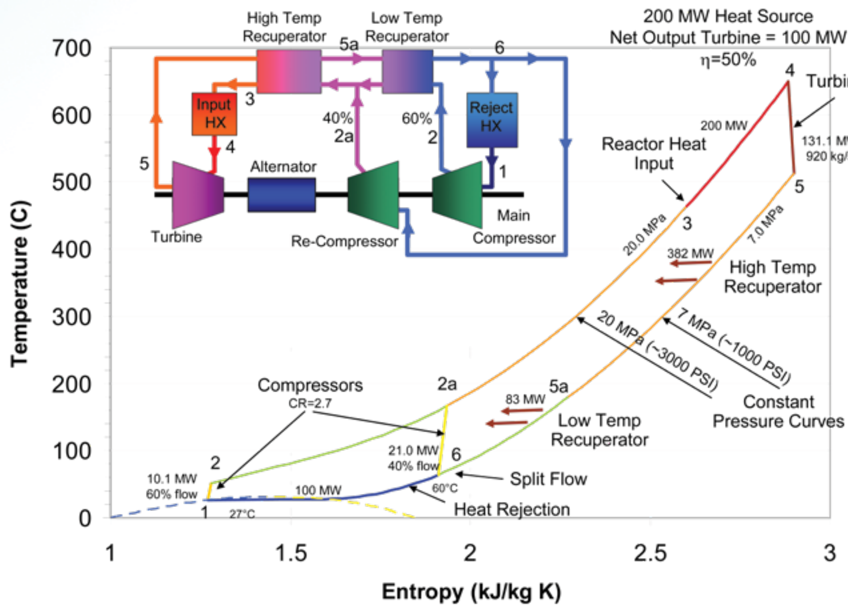
A sCO_2 Brayton Cycle Design

Of many governmental agencies, companies, research and academic labs, Sandia National Laboratories has been an early leader in developing sCO_2 power technology.

In 2011, Sandia published [3] a design study of a 100 MWe supercritical CO_2 Brayton cycle power plant, with a gas-cooled 200 MWt nuclear reactor as the heat source to power the cycle.

Figure 2 shows a flow schematic of this split-flow (flow recompression), sCO_2 Brayton cycle 100 MW output power plant that was analyzed. It is accompanied by a very clear and elegant temperature-entropy diagram that gives a detailed account of the thermodynamic properties of the sCO_2 working fluid at every point in the cycle. I refer the reader to the Sandia report [3] for more details, but a few key points are as follows:

Figure 2. Sandia Flow Schematic and T-S Diagram for the Split-Flow Brayton sCO_2 Cycle [3]



1. The calculated thermal efficiency of the 100 MW Sandia sCO_2 power plant is 50%. One can compare that to the air breathing General Electric LMS100 simple cycle, intercooled gas turbine with a 119 MW output. This unit, popular with independent power producers, has the world's highest simple cycle thermal efficiency of 44.7%, which is about 5 points lower than the Sandia calculated sCO_2 efficiency.
2. The peak engine temperature shown in the sCO_2 cycle in Fig.2 is 650 °C (1202 °F), well within the safe operating temperature range of uncooled nickel-cobalt turbine blades. In other words, there would be no need for expensive cooled (and power robbing) hardware.
3. The sCO_2 cycle pressures shown in Fig. 2 are high, at 7-20 MPa (1000 - 2000 psia) which are necessary to operate and have a supercritical fluid (see Fig. 1). (Recent designs feature pressures as high as 30 MPa.)

In summary, the Sandia design study is an excellent example to show possibilities that sCO_2 Brayton cycle power plants may provide for the future. Executing such a 100 MW design is a next important step. Currently, toward that goal, serious developments are occurring in the 10 MW range [4]. Stay tuned!

1. CIBSE Journal, 2012, "Module 47: Going transcritical with CO_2". <https//cibsejournal.com/cdp/modules/2012-12/>
2. Frutschi, Hans Ulrich, 2005, *Closed-Cycle Gas Turbines*, ASME Press.
3. Parma, Edward J., et al, 2011, "Supercritical CO_2 Direct Cycle Gas Fast Reactor (SC-GFR) Concept", Sandia National Laboratories Report SAND2011-2525, May.
4. Marion, John, et al, 2019, "The STEP 10 MWe sCO2 Pilot Plant Demonstration", Proc. ASME Turbo Expo 2019, Phoenix, June 17- 18, Paper GT2019-91917.

WRITING TURBOJET HISTORY…TODAY

By Dietrich Eckardt, *Prof. Dr.-Ing.*
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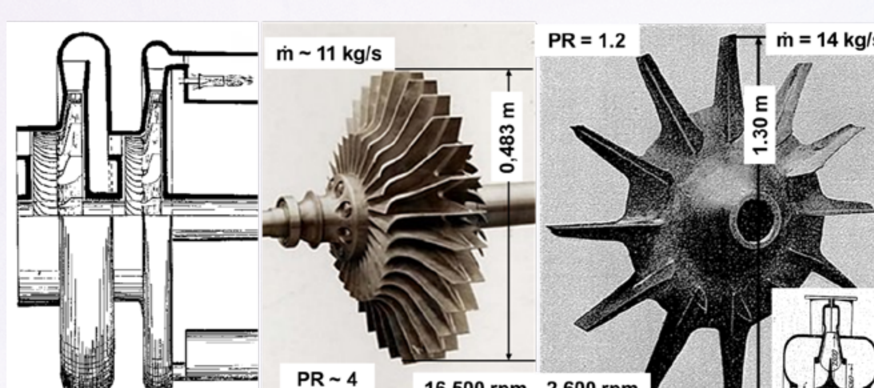
The author, winner of ASME's 2017 Engineer-Historian Award for *Gas Turbine Powerhouse*, is finishing *Jet Web*, a newly adapted history of the turbojet.

Well-founded literature represents our present understanding of the history of turbojet development. One would think any new insights are relatively rare. The great lifetime works of turbojet protagonists Sir Frank Whittle (1907-1996) [1] and Hans-Joachim Pabst von Ohain (1911-1998) [2] have been highlighted in numerous books, cementing the perspective of parallel, independent inventions as part of an old, all-overarching German-British antagonism.

While writing Gas Turbine Powerhouse [3] on the history of power gas turbines, the author also recognized the special role of the Swiss Brown Boveri Co. (BBC) and of their axial compressor design lead in the 1930s on the emerging turbojet developments in England, Germany and the United States. The collected materials were so interesting, that they could be used as basis for more in-depth studies on turbojet developments in the country triangle Great Britain - Germany - Switzerland, beyond the isolated Whittle and von Ohain achievements. The title term 'Jet Web' was born to illustrate some largely overlooked 'Connections in the early development history of aero gas turbines'. Supplementary to the many existing technical historians' masterpieces, which were based mostly on post-war material collections and oral history interviews, now archive and internet searches by the author revealed in addition many hidden, often personal interconnections amongst the various national endeavors. In combination with the author's own professional engineering experience in this field (DLR, MTU, ABB/Alstom), this created many astonishing, new insights to be presented in Jet Web; in what follows are presented two typical examples.

Whittle's Centrifugal Impeller Origin

The origin of the characteristic, dual-flow centrifugal impeller of Whittle's turbojet concept after 1936, as illustrated in the mid-section of the attached picture A, is unknown in the official literature. His first patent GB347,206 with priority 16 January 1930, combined somewhat deliberately two axial inducer stages and one centrifugal impeller, just—as he confessed—to get patent coverage eventually on both compressor types. It is known that Whittle's turbojet concept as presented to Griffith and the Air Ministry in October 1929 consisted of a two-stage centrifugal compressor, as illustrated in the left detail picture. His supercharger studies in 1928 and his proposals for a free-wheeling, self-propelled supercharger might have helped him on the way to the double-flow solution. Whittle picked it certainly to save weight, to shorten the shaft length and thus to increase power density at reduced frontal diameter, but were there stimulating forerunners? Strong suggestions in favor of an influence of the Norwegian Ægidius Elling, who had used a very similar rotor set-up in 1924, had been turned down, quite friendly, by Whittle himself, still in 1968. Surprisingly, the solution is a much older, 1907 first industrial usage of a dual-flow turbo-blower on the basis of a patented design of the French Auguste Rateau (1863-1930), US827,750 with priority 7 August, 1906, built for the Siemens-Martin steelworks at Rote Erde, Aachen, Germany, right detail picture, and shown already, but so far unnoticed in Gas Turbine Powerhouse, p. 47 (Jet Web, Ch. 6.3.1).

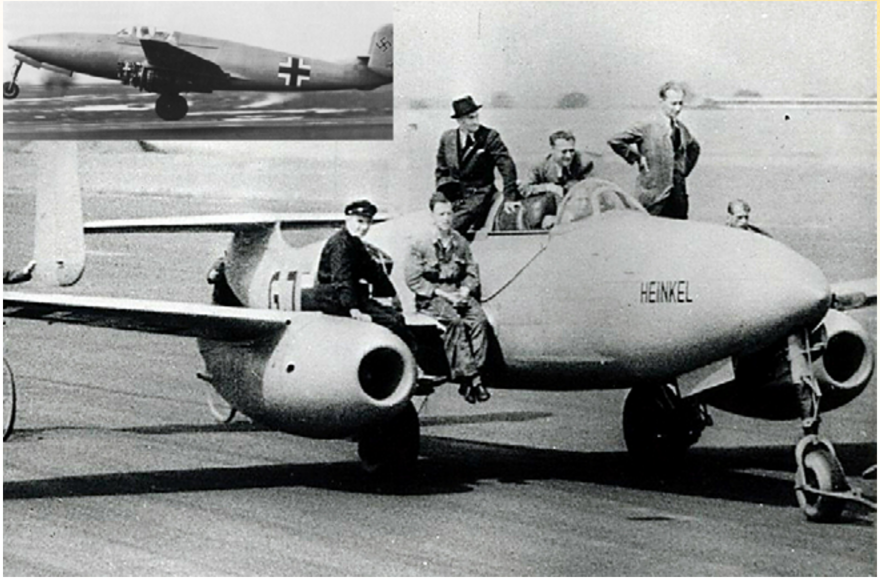


A. Genesis of the Whittle Impeller: 2st. centrifugal compressor GT project, Oct. 1929 (l), WU experimental engine, 1st Rugby test 12 April 1937: dual-flow compressor impeller (m), Brown Boveri - Rateau dual-flow turboblower impeller, Aachen, D 1907 (r) © I.Whittle (m)

The First Turbojet Fighter

Again, as a result of thorough research, the attached picture B allows a unique atmospheric insight into one of the leading German turbojet aircraft/engine development teams—from Heinkel in 1942. (Jet Web, Ch. 8.1) The main picture shows the Heinkel He 280, the first turbojet-powered fighter aircraft in the world, in July 1942 at Heinkel, Rostock-Marienehe, where on 27 August, 1939, also the first turbojet-powered He 178 flight had taken place. From the beginning, Heinkel struggled with the tasks of developing aircraft and engine in parallel, Hans von Ohain's unchanged centrifugal engine concept, the HeS 8 with intended 700 kp take-off thrust was running into difficulties. Finally, on 30 March, 1941, the first flight of He 280-V2 (test version #2) took place, piloted by Fritz Schaefer; however—small cause, big effect—due to fuel leaks, they decided to remove the engine cowlings, see picture inset.

The Heinkel development crept on up to 5 July, 1942, when Schaefer also brought He 280-V3 to air. But the Messerschmitt competition was now already very close; Heinkel had squandered a project lead of at least one year, when Fritz Wendel took off the Me 262-V3, first time Jumo 004 turbojet-powered on 15 July, 1942, from Messerschmitt's Leipheim airstrip. Heinkel, now under pressure, decided to go for a He 280 promotion movie, by re-enacting the first flight in a triumphant set-up—and with closed engine cowl. The picture—actually copied out of the movie sequence—shows behind the pilot Fritz Schaefer from—left-to-right—Hans Antz (1909-1981), together with Helmut Schelp responsible at the Reich Air Ministry for the synchronized turbojet aircraft/ engine development in Germany, Dr. Hans von Ohain, Heinkel's young engine man, and to the right, the test pilots Peter and Warsitz. However, all PR effort at Heinkel was in vain, when the He 280 was officially cancelled on 22 March, 1943—and the movie starring engineers remained an episode; the path for the Me 262, the first operational turbojet fighter, was free.



B. Rostock meets Hollywood: He 280 1st flight re-enactment in July 1942, pilot F. Schäfer, two unknowns on right wing; behind Schaefer, left to right: H. Antz (with hat), H. v. Ohain, and test pilots G. Peter and E. Warsitz; original first flight on 30 March 1941 (inset) © V. Koos

1. Golley, John, 1987, *Whittle - The True Story*, Smithsonian Press.
2. Conner, Margaret, 2002, *Hans von Ohain: Elegance in Flight*, AIAA.
3. Eckardt, Dietrich, 2014, Gas Turbine Powerhouse, 2nd ed., De Gruyter.

ASME IGTI Student Scholarship Program

go.asme.org/scholarships

ASME International Gas Turbine Institute has a long and proud history of providing scholarships to students who show promise for their future profession in the turbomachinery field. The aim is to attract young talent to the profession and reward their commitment, favoring their upcoming enrollment and active participation. The scholarship is to be used for tuition, books and other University expenses. The check will be made out to the University on the student's behalf.

APPLY TODAY!

applications due

February 18
for Undergraduate applicants

March 4
for Graduate applicants

ASME 2021 GAS TURBINE INDIA CONFERENCE & EXHIBITION

Submit Abstract by May 10, 2021 at *event.asme.org/GT-India*

The 2-day event attracts the industry's leading professionals and key decision makers, whose innovation and expertise are shaping the future of turbomachinery. Authors and presenters are invited to participate in this event to exchange ideas on research, development and best practices on Gas Turbines and allied areas. The conference is an excellent opportunity to initiate and expand international co-operation.

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- A Scholar Lecture
- Featured Lectures
  - Aircraft Engine Technology Award Lecture
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- networking capabilities
- more opportunities in the program to connect with your community
- Q&A after each presentation