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AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
International Gas Turbine Institute / 1235 North Loop West, Suite 706, Houston, Texas 77008 / go.asme.org/igti

Letter from the Editorial Committee

DEAR READERS,

With Turbo Expo 2026 just around the corner, we are excited to open this April / May issue by spotlighting our upcoming gathering in Milan, Italy, June 15–19. In a special feature article, Milan is highlighted as the host city for our global turbomachinery community gathering. From Leonardo da Vinci's pioneering studies of vortices and fluid motion to Italy's historic contributions in aviation, electrification, and industrial innovation, Milan embodies the spirit of engineering curiosity and bold thinking. As we convene under this year's theme, "Beyond Resilience – Power and Propulsion Systems for a Fast-Changing World," we do so in a place whose legacy mirrors the innovation and collaboration that define our field today.

This issue also explores transformative technologies shaping the future of clean and efficient power. Dr. Rakesh Bhargava examines the evolution and renewed promise of closed cycle gas turbine (CCGT) systems, particularly when integrated with high-temperature reactors and small modular reactors. By leveraging intercooling, recuperation, and alternative working fluids such as helium and CO_2, CCGT systems demonstrate strong potential for high thermal efficiency and reduced greenhouse gas emissions—positioning them as compelling solutions for reliable, low-carbon energy generation. Complementing this systems-level perspective, Dr. Katie Kirsch of RTX Technology Research Center presents advances in computational design and additive manufacturing for next-generation heat exchangers. Through topology optimization and multi-physics modeling, these ultra-lightweight, power-dense components are enabling more compact and efficient supercritical CO_2 systems, demonstrating how digital engineering and advanced manufacturing can unlock entirely new levels of performance.

Together, these articles reflect the dynamic evolution of turbomachinery—honoring history, advancing hardware innovation, and accelerating sustainable energy pathways.

As we prepare to gather and see many of you in Milan, we would like to extend our utmost gratitude to all who make Turbo Expo possible: attendees, members, reviewers, and organizers. We are looking forward to coming together to exchange ideas, challenge boundaries, and shape the future of propulsion and power systems.

Warm regards,

DR. TAMY GUIMARÃES
On behalf of the Editorial Committee
ASME Global Gas Turbine News

Italy and Milano: A Cradle of Propulsion and Energy Innovation

Figure 1. Fluid Vortex, Leonardo Da Vinci, Codex Leicester, Windsor RL12660v

We build our future on the genius of our ancestors, and few cities embody this legacy like Milano. Here, Leonardo da Vinci envisioned concepts that still shape modern engineering: his studies of vortices and fluid dynamics—captured in the Codex Leicester—anticipate today's CFD simulations and turbine design.

Milano became a hub of industrial progress: the Regina Margherita Thermoelectric Plant (1895), powered by a Franco Tosi steam engine, marked Italy's turn toward electrification. The city also witnessed Enrico Forlanini's pioneering work in vertical flight with his steam-powered helicopter (1877). Italian aviation reached global fame with the Macchi M.C.72 holding since 1934 the world speed record for seaplanes at 709 km/h. In 1953, Enrico Mattei chose Milano as ENI's headquarters, to rebuild post war Italy. Nuovo Pignone, established 1842, developed energy technologies with early hydrogen compressors, a legacy carried forward today by Baker Hughes with hydrogen ready gas turbines. Since 1863 Ansaldo Energia, has demonstrated leadership and flexibility in turnkey plants. Italian ingenuity also produced Olivetti's Programma 101, the world's first desktop programmable calculator used by NASA. For enthusiasts, Milano's Museum of Science offers Leonardo's galleries and many of these historic inventions.

Technological Innovation continues through Politecnico di Milano, founded in 1863, now a major research hub in turbomachinery, hydrogen, and sustainable energy, partnership with industry and international projects. Don't miss the opportunity to visit their labs during the conference. Listing every Italian university engaged in propulsion and energy research is impossible, even AI-generated lists overlook some. I recommend discovering them at technical sessions.

All these reasons make Milano an ideal setting for Turbo Expo 2026. This will mark my 9th Turbo Expo: year after year I've observed the conference evolution, as captured by the 2026 theme: **Beyond Resilience – Power and Propulsion Systems for a Fast-Changing World**.

Our turbomachinery community responded effectively to global challenges. The COVID-19 pandemic shifted Turbo Expo temporarily online in 2020, and the 2022 energy crisis underscored the need for resilient, safe, affordable power systems. Trends at Turbo Expo reflect this shift: increasing focus on hydrogen and alternative fuels, digitalization, Artificial Intelligence and Machine Learning, decarbonization pathways, supercritical CO_2 cycles, energy storage and Life Cycle Assessment with economic evaluation all aimed at meeting the rising demand for clean, cost-effective energy, while safety and reliability remain foundational.

Leonardo, with his sensitivity and curiosity, reminds us that creativity thrives when diverse minds work together. Few people possess his breadth of genius, but we can replicate his approach by connecting different perspectives—across genders, cultures, generations, and disciplines.

Turbo Expo offers this environment: a place to connect with industry, academia, and government; to share insights, listen, question, and synthesize; aiming for a holistic approach to develop sustainable solutions that promote leadership, safety, and innovation in a rapidly changing world.

Join us in Milano to tackle today's most pressing energy and turbomachinery challenges. Remember that advanced discounted registration closes on May 12.

See you at a remarkable Turbo Expo 2026 in Milano!

Angela Serra
Local Liaison Committee Member, Turbo Expo 2026

Closed Cycle Gas Turbines Can Help in Mitigating Greenhouse Gas Emissions

Rakesh K. Bhargava, Ph. D., ASME Fellow

Founder & President, Innovative Turbomachinery Technologies

SUMMARY

The power generation systems developed using closed cycle gas turbines combined with nuclear fuel, particularly, small modular reactor (SMR) design, have shown potential in reducing greenhouse gas emissions including reduced plant's footprint, reduced maintenance cost, and increased hot gas-path components life. The development of such technologies and experiences attained thus far including future potentials are briefly discussed here.

BRIEF OVERVIEW ON THE DEVELOPMENT OF CCGT TECHNOLOGY

In a closed cycle gas turbine (CCGT), unlike an open cycle gas turbine, having capability of using different working fluids (air, helium, CO_2, N_2, including gas mixtures), combustion products do not mix with the working fluid. Both open and closed cycle gas turbines are contemporaneously developed technologies as the first unit of each design became successfully operational in 1939. The world's first utility size open-cycle gas turbine (GT) plant, designed and built by Brown Boveri & Cie of Baden, Switzerland and installed in Neuchâtel, Switzerland became operational in July 1939. Whereas, the first experimental CCGT power generation system (designated AK-36), designed and developed by Escher Wyss AG and installed at their plant in Zurich, Switzerland, became operational in summer of 1939. It is worth mentioning that 1939 became a historic year for the gas turbine technology as also the first aviation gas turbine, HeS-3B turbojet engine designed by von Ohain at Heinkel Aircraft Company in Germany, successfully powered Heinkel He-178 aircraft in August 1939 and started the world's Jet-age.

The first open-cycle electric power generating GT having turbine inlet temperature (TIT) of 550 °C and pressure ratio of 4.4 had net power capacity of 4 MW with thermal efficiency of 17.4%. Whereas, the first CCGT-based power generation system with the working fluid air consisted of the following: spilt-shaft design with high-pressure (HP), low-pressure (LP), and medium-pressure (MP) compressors driven by a HP turbine at 8000 rpm and LP turbine connected to the electric generator at 3000 rpm; one intercooler each between LP and MP and MP and HP compressors, one each recuperator and oil-fired heater (to heat the working fluid air) with its combustion air preheater, and a pre-cooler. This system, designed with compression ratio and compressor inlet pressure of 3.8 and 6.3 bar, respectively and net power output of 2 MW at TIT of 687 °C, attained thermal efficiency of 32.6% [1]. This significant increase in thermal efficiency of the CCGT system compared to the first open-cycle GT was possible due to implementation of intercooling and recuperation processes.

The working fluid in a CCGT system is supplied to the compressor at high pressure which helps in reducing the overall cycle pressure ratio and size of compressor and turbine sections. The working medium in a closed loop being clean prevents detrimental effects (corrosion and erosion) of turbine components resulting due to combustion products and thus extending life of critical components. The need of inlet air filtration, a severe problem experienced with conventional GTs operating in a contaminated atmosphere, is eliminated and thus reducing environmental impacts (no compressor fouling in CCGTs, a major cause of performance deterioration with open-cycle GTs).

After the first commercial CCGT plant built in 1949 and during 1950s to 1970s, few CCGT plants were built mostly in Europe and USSR with limited (30 MW maximum) net power output due to heater's materials constraints and its increased size resulting in the reduced market compared to plants with open-cycle GTs. One large-size CCGT plant, named Oberhausen II and installed in Oberhausen, Germany, with design power output of 50 MW using coke-oven gas-fired heater and helium as the working fluid, became operational in 1974. This plant, designed to supply electric power and district heating, was developed to gain experience with large power rated helium turbine as a part of the joint German-Switzerland high temperature reactor project (HHT project) planned to use helium as the reactor coolant and the working fluid in a direct cycle arrangement with CCGT system. The Oberhausen II plant with TIT and turbine inlet pressure of 750 °C and 27 bar, respectively, designed with thermal efficiency 34.5% could only achieve 30 MW power output at 23% thermal efficiency due to poor design of turbomachinery components with lower efficiency, increased helium flow consumption for cooling and sealing than the design value, and higher sealing leakage & pressure losses [2].

In late 1950s, studies were initiated to improve efficiency of then existing conventional nuclear power plants, such as light water reactors (LWR), through the use high temperature reactors (HTR) with helium and CO_2 as the nuclear core's coolant gas. First three experimental small helium-cooled HTR plants were built and operated during 1960s to 1980s: Dragon plant in UK (nuclear core's outlet gas temperature of 750 °C); Peach Bottom-1 plant in the U.S. (core's outlet temperature 728 °C and steam PCS (power conversion system) system with 40 MW power output); and AVR plant in Germany (with pebble-bed reactor, core's outlet temperatures of 650-850 °C and steam PCS) with power output 15 MW.

During early 1990s, development of the GT-MHR (gas turbine-modular helium reactor) directly coupled with CCGT-based PCS at General Atomics in the U.S. and later the joint development work with Minatom of Russia showed that such a system could achieve 50% thermal efficiency.

The CCGT-based PCS system utilizing nuclear fuel with helium as the working fluid (see Fig. 1) consisted of intercooling and recuperation processes for reducing compression work and energy recovery from the GT exhaust, respectively for enhancing the system's performance. The CCGT system with design conditions as noted in Fig. 1 had capability to produce 286 MW power with 47.7% thermal efficiency at TIT and pressure ratio of 850 °C and 2.8, respectively. It is important to note that the first F-class GT, GE Frame 7F becoming operational in June 1990 using the conventional open-cycle, had thermal efficiency of 34.5% at TIT and pressure ratio of 1260 °C and 13.5, respectively and, therefore, clearly identifying benefits of the GT-MHR system. The GT-MHR design using CCGT system showed numerous advantages compared to the LWR system: higher thermal efficiency (47% to 51%) compared to 32% for the LWR system at the time; a smaller housing structure; no containment building as required for the LWR system; modular design facilitated pre-construction and remote assembly at the site, thus significantly reducing construction costs and length of time required. High efficiency of the GT-MHR design helped in producing about 50% less high-level radioactive waste and about 100% less thermal discharge to the environment than the comparable sized LWR system [3].

In recent years with significant research and development work in progress for adopting the SMR technology for energy intensive applications such as data centers, artificial intelligence, including green hydrogen production, desalinization process in an effort to create carbon-neutral energy system, the CCGT based power generation technology combined with comparative benefits identified here might become commercially competitive in coming years which could not be used earlier because of lack of demand of small power capacity nuclear based power generation compared to the conventional systems. A recent forecast suggested that the SMR market could grow up to 9% annually and be worth at least US$13.4 billion by 2032 implying strong market for gas turbines in coming years [4]. ◆

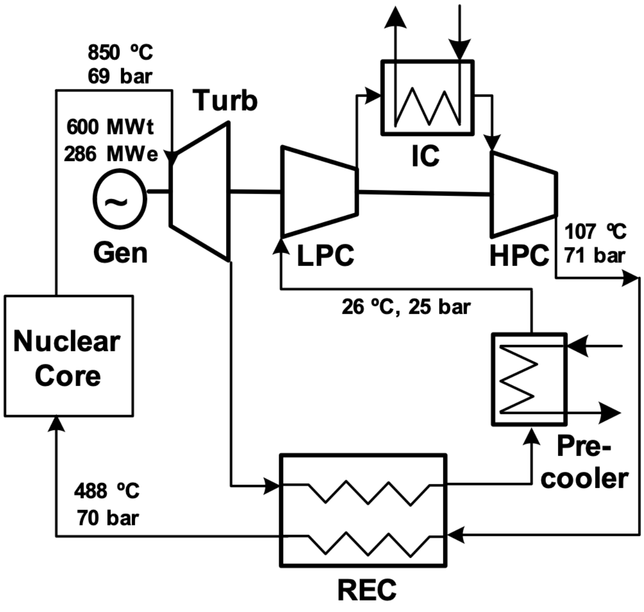

Figure 1. Flow diagram of the power generation system using closed cycle gas turbine with high temperature small modular reactor (excerpted from [3])
(Note: HPC, IC, LPC and REC represent high pressure compressor, intercooler, low pressure compressor, and recuperator, respectively)

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Next Generation Design Tools: Enabling Ultra Lightweight, Power-Dense Heat Exchangers

Dr. Katie Kirsch

RTX Technology Research Center (RTRC)

Heat exchangers (HX) are ubiquitous in energy systems, including in power generation from both ground-based and aviation engines. State-of-the-art (SOA) HXs use standard manufacturing processes, such as stamping and brazing, which often limit the HX architectures to conventional designs. Plate-fin and shell-tube configurations are among those conventional designs and have proven reliable across a wide variety of environments. However, the requirements of next generation systems demand increased capability and will push the limits of conventional HX manufacturing. Moving beyond today's power generation systems challenges us, the technical community, to improve our manufacturing ability, design methods, and material technologies.

One dedicated effort to develop advanced HXs came through ARPA (Advanced Research Projects Agency)-E's HITEMMP (High Intensity Thermal Exchange through Materials and Manufacturing Processes) program DE-AR0001957—teams were tasked with developing 800^{0}C- and 250 bar- capable HXs that were highly compact, durable, and cost-effective. The application was a recuperator in a supercritical carbon dioxide (sCO_2) power generation system; sCO_2 power generation cycles are efficient and power-dense, with extremely compact turbomachinery. That compactness is a direct result of the sCO_2 itself; the CO_2 remains above its critical point—31.1^{0}C and 73.8 bar—throughout the cycle, making it highly efficient in generating power. Additionally, the upper limit on temperature is often pushed in these cycles to drive higher thermal efficiency. Components, therefore, must be designed to withstand this high pressure, high temperature environment.

RTX, along with several other HITEMMP performers, chose to build the HX using Laser Powder Bed Fusion (LPBF), a metal-based additive manufacturing (AM) method. The result was a fully additive HX, tested with sCO_2 at 800^{0}C and 250 bar (1472 ^{0}F, 3600 psi), with mass-based power density greater than 12 kW/kg—3X more power-dense than SOA.

Despite the success in HITEMMP, the team spent significant time manually iterating on the design of the HX and the header. The header was a custom, fully self-supporting design that connected the inlet and outlet ports to the thousands of small channels in the core. However, the headers ended up contributing little to the heat transfer performance, despite being the largest and heaviest portion of the HX. That characteristic—bulky headers that contribute minimally to performance—is common in HXs, depending on how much of the manifolding is considered part of the HX. But, we weren't building a common HX. We should be able to change that narrative with AM. The natural question then arises: how can we shrink the header size by using computational design tools?

Starting a design from scratch is a daunting task. To bound the problem, physics-based design tools can help; when coupled with manufacturing rules, these tools can drive innovative, feasible solutions quickly. For this reason, RTRC has been focused on building robust, multi-physics design tools for advanced components, such as heat exchangers, for over a decade, with the latest result showcased in a follow-on ARPA-E program to HITEMMP called TOPOLOGY program DE-AR0001473.

The technique used in RTRC's design tool is called topology optimization (TO). TO has been widely used in the community, perhaps most visibly in structures applications such as designing lightweight trusses or brackets. Solid material is deposited in a design domain based on an objective function to minimize stress or minimize compliance. In basic thermal fluids TO, the idea is the same, but the material is a fluid. The objective function is to minimize pressure drop or maximize flow uniformity. In thermal fluids TO, a designer starts with a bounding box around the problem and defines the location and boundary conditions for each inlet and outlet. Throughout the design iterations, the TO approach can add or remove material—one fluid material—in any location. Material is deposited where the physics solution dictates.

Two-fluids TO represents one level of complexity beyond the basic approach. Two fluids run through the same design domain, but only one fluid can occupy a given cell. Material is deposited where the physics solutions dictate and when the material does not block the path of the other fluid. The result is a set of two fluid streams that are co-optimized. Two-fluids TO is needed, for example, in a counterflow HX header, where hot and cold streams run opposite each other.

An additional step in complexity is added when multiple types of materials—n-number of fluids and n-number of solids—and multiple physics solutions are needed to solve a complex problem with competing objectives. This level of complexity was needed for the TOPOLOGY HX, which used two fluids and one solid, and needed to solve for both the stress levels in the solid and the pressure drop of the fluids.

In multi-material, multi-physics TO, all materials are deposited in the same domain, but, as in two-fluids TO, only one material can occupy a given cell. Multiple physics solutions are run in each design iteration, including computational fluid dynamics (CFD) for the fluids and finite element analysis (FEA) for the solids. Material is deposited where its physics solutions dictate, when the material does not block the path of another material, and when each material can maintain a continuous flow path or load path. In situations where two or more materials want to occupy the same cell, the design iteratively progresses toward a solution with the lowest penalty to the overall objective function.

As mentioned, manufacturability rules are paramount, especially for the organic shapes that emerge from TO. Manufacturability constraints in the design tool are embedded within the optimization iterations themselves. That is, material is deposited when a fourth criterion is met: the material must be self-supporting. Manufacturability constraints can be applied regardless of the presence of solid material in the optimization. Figure 1 shows

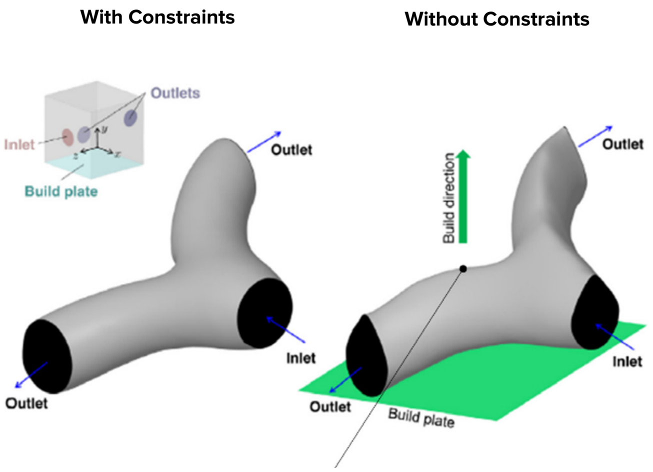

Figure 1. Self-supporting structures created during the optimization process based on build direction [1].

a basic, one-fluid TO run with and without AM constraints. The fluid passage on the right shows the canonical teardrop-shaped channels, which allow the design to be built without internal support structures. In multi-material, multi-physics TO, the manufacturing constraints are applied to the solid domain(s).

We applied the latest design framework in the ARPA-E TOPOLOGY program, where the design domain contained the same inlet and outlet ports as the HITEMMP header. The boundary conditions were the same as in HITEMMP—high temperature and high pressure sCO_2 for an sCO_2 power generation cycle. The objective function was to minimize pressure drop in both the hot and cold fluids while minimizing stress in the solid material. Ultimately, the tool produced a header that was 30% lighter and 50% smaller than the HITEMMP header. As in HITEMMP, the TOPOLOGY HX was tested with sCO_2 at 800^{0}C and 250 bar (1472 ^{0}F, 3600 psi), showcasing a 40% higher power density—>4X higher than SOA. A comparison between the full HITEMMP HX and the TOPOLOGY header is shown in Figure 2. The TOPOLOGY header shows organic-like fluid pathways wrapped in solid material, all of which were created using physics simulations coupled with an advanced optimization solver.

The next generation of power systems will require a next generation heat exchanger. Relying solely on current SOA architectures limits how advanced that next generation can become. Plate-fin and shell-and-tube HX architectures are defined with conventional manufacturing rules in mind, which limit both their design freedom and their durability in harsh environments. More advanced manufacturing techniques, such as additive manufacturing, allow for more varied form factors, but only when coupled with design tools that can consider multiple physics, multiple materials, and manufacturability. With this work, we are demonstrating the utility of computational design and are working to make that first step in a clean-sheet design less daunting, driving ever closer to tomorrow's power generation engines.

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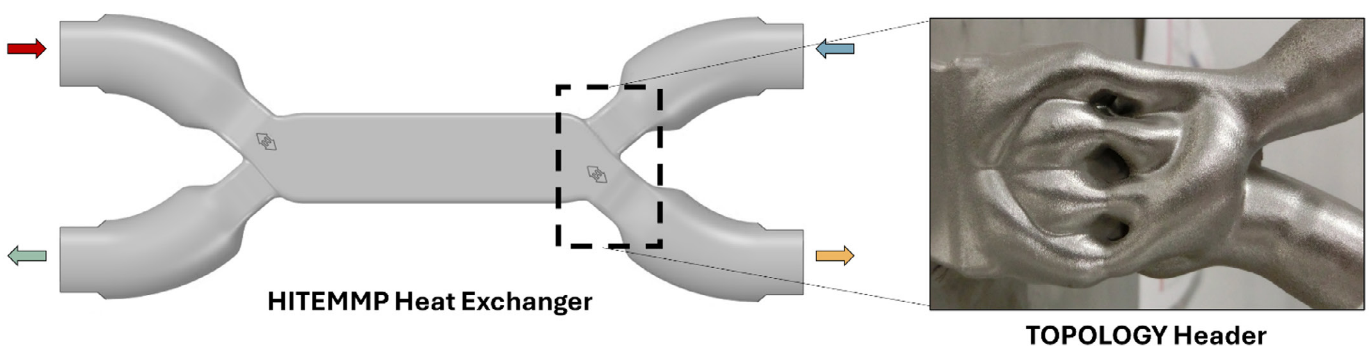

Figure 2. (Left) Full HITEMMP HX, showing counterflow headers plus HX core; (right) topology-optimized counterflow header from TOPOLOGY program, which mates with the same HITEMMP HX core.

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Awards Information

ASME IGTI AIRCRAFT ENGINE TECHNOLOGY AND ASME IGTI INDUSTRIAL GAS TURBINE TECHNOLOGY AWARDS

DEADLINE OCTOBER 15

For nomination details, click here.

ASME R. TOM SAWYER AWARD

DEADLINE SEPTEMBER 15

For nore nomination details, click here. Questions may be sent to igtiawards@asme.org.

ASME IGTI DILIP R. BALLAL EARLY CAREER AWARD

DEADLINE AUGUST 1

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This year top experts and decision-makers will gather in-person to exchange ideas and experiences to develop and discuss the implementation of safe, reliable carbon neutral solutions while shaping the future of the turbomachinery industry. Turbo Expo will serve as a synergetic platform for government, academic, research, and industry professionals to discuss multidisciplinary approaches for decarbonization.

The 5-day conference will include hundreds of live technical presentations, tutorials, and panels. The conference offers a series of unopposed plenary sessions highlighting the Turbo Expo 2026 theme, Beyond Resilience - Power and Propulsion Systems for a Fast-Changing World.

Monday's Keynote: *Beyond Resilience - Power and Propulsion Systems for a Fast-Changing World*

In addition, Turbo Expo 2026 will hold a 3-day exhibition featuring professionals ready to share their products and services with the turbomachinery industry. The exhibition, running from Tuesday to Thursday, will showcase afternoon open hosted receptions allowing attendees to build out their professional network and identify future opportunities.

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