Two World Records

About to go commercial is the most powerful gas turbine ever, within the most efficient combined cycle power plant ever. No wonder: The underlying technology is some of the most impressive – ever.

By Eric Johnson

Photo: Siemens

Siemens' Proven Combined Cycle Power Plant SCC5-8000H 1S

- **Location:** Irsching near Munich, Germany
- **Performance (net)*:** 578 MW
- **Efficiency (net)*:** 60,75 %
- **Emissions at base load:** NOx < 25 ppm / CO < 10 ppm
- **Fast hot start-up** < 30 min

(*) Irsching 4 reference site conditions, world record test run results, TÜV certified

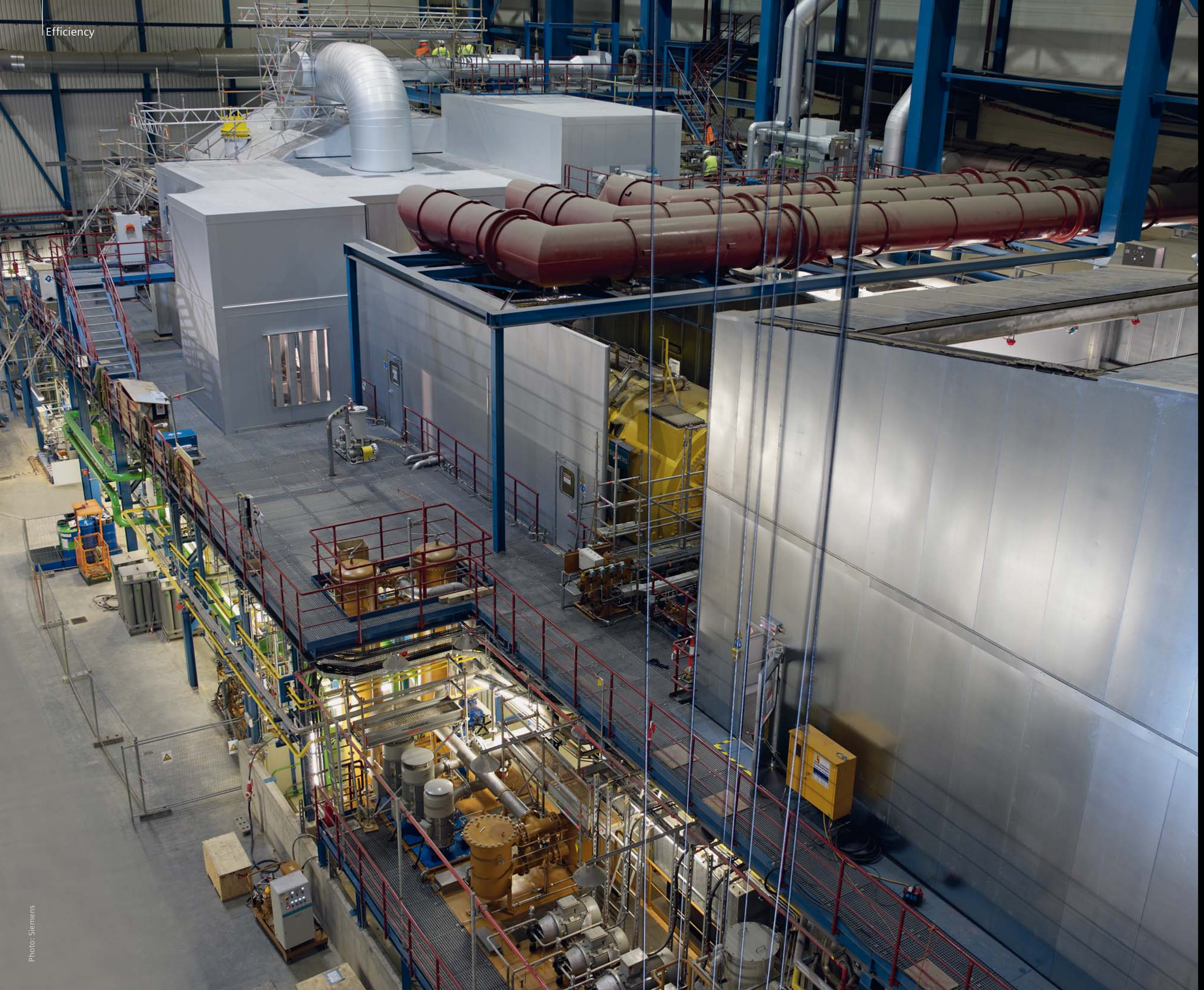
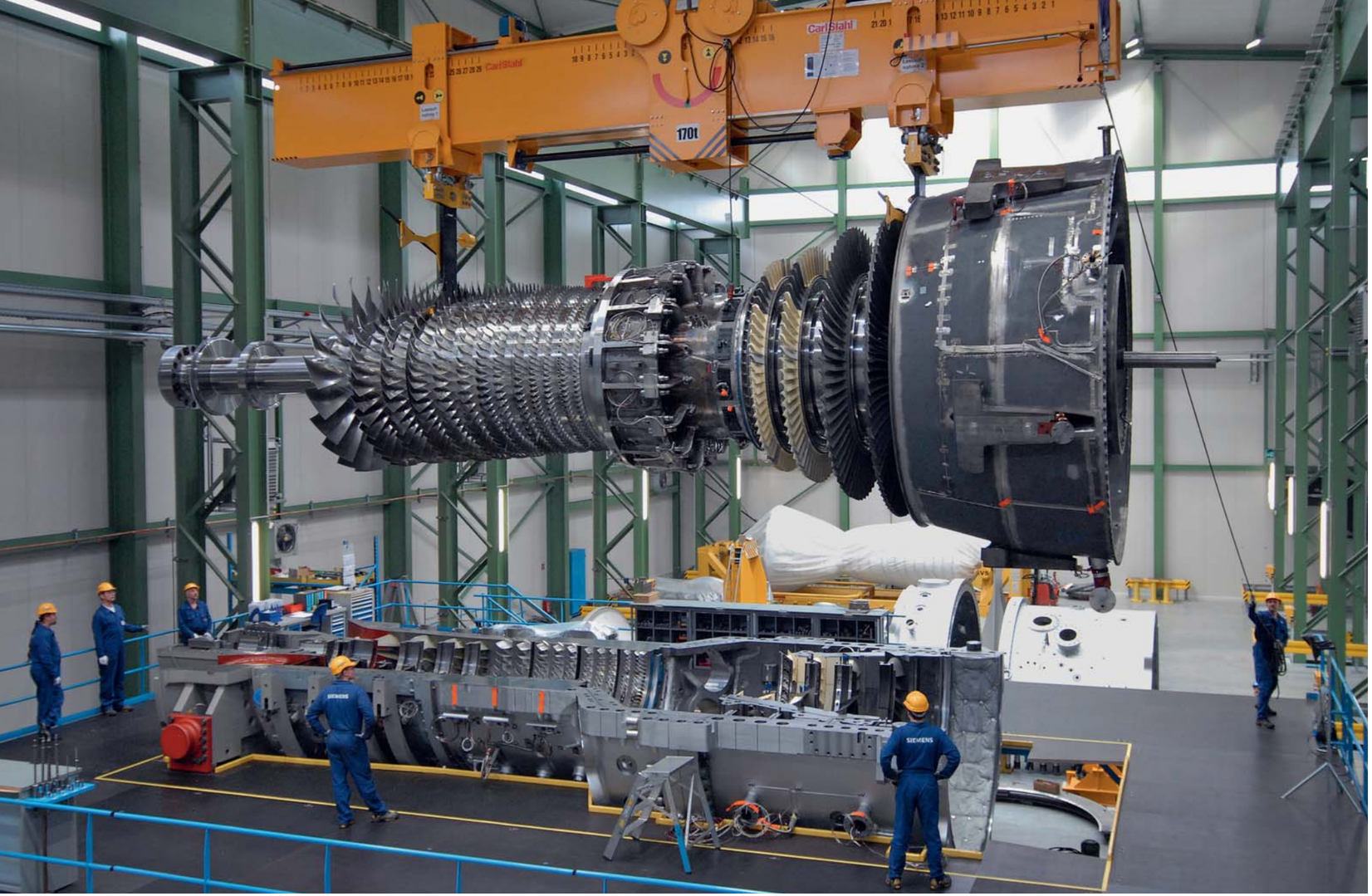


Photo: Siemens

Inside the Turbine Building

Components include:

- Gas turbine SGT5-8000H
- Steam turbine SST5-5000
- Water/hydrogen-cooled generator SGen5-3000W
- Power plant automation system SPPA-T3000
- Siemens triple-pressure reheat heat recovery steam generator (HRSG) with BENSON HP evaporator
- Advanced steam parameters and speed-controlled boiler feed pumps for highest combined cycle efficiency
- Single-side condenser



Final stage of assembly: The rotor is inserted into the tight-fitting turbine shell.

Photo: Siemens

> “These developments constitute an advance to a completely new realm of technology.”
>
> Klaus Hammer, Global Fleet Manager Combined Cycle Gas Turbines, E.ON Generation GmbH

Roger Bannister’s four-minute mile: Oxford, 1954. Michael Phelps’s eighth gold medal: Beijing, 2008. Roger Federer’s 16th Grand Slam: Melbourne, 2010. For sports cognoscenti, these are touchstones. Reminded of them, fans nod knowingly, remembering the performer, the place, and the date. The same is true for doyens of power production. Soon they will be nodding in acknowledgement of two new outstanding achievements. Performer: Generating Plant 4. Place: Irsching, a small town 90 kilometers north of Munich. Date: May 9, 2011. The performance: one world record for gas turbine power rating, at 375 MW; and another for combined cycle efficiency, at 60.75 percent at a power output of 578 MW. As for efficiency, Irsching 4 – which also incorporates a 600°C steam generator and a 200-MW 600°C Siemens steam turbine – is first to crack the magical barrier of 60 percent, verified by the German TÜV.

The breakthrough to over 60 percent efficiency was driven by a raft of technology tweaks pioneered by Siemens: reduced cooling air, torrid turbine and cycle temperatures, tighter design tolerance; all done without external cooling in the gas turbine and using further innovation in the steam-water cycle and heat recovery steam generator. All are evolutionary, building on previous know-how, but taken together, these developments constitute an advance “to a completely new realm of technology,” according to a statement by Klaus Hammer from E.ON, the utility that owns and operates Irsching. Michael Suess, Siemens CEO of Sector Energy, agrees: “This plant is a trendsetter.”

Like most record breakers, E.ON and Siemens are clearly proud of what they have wrought. The official handover of the plant is planned for end of July; after a final period of reliability run, the ceremonies are scheduled for September 2011. But in this ongoing arms race of size and efficiency, much more is at stake than mere bragging rights for engineers. Larger, more efficient, and more operating flexibility pays off by cutting per-kWh investment, operating costs, emissions, and start-up times. Unlike conventional gas-fired power plants that run mainly at peak loads, Klaus Hammer from E.ON says, Irsching 4 is economic enough to run a long period of the year. And in contrast to an average coal-fired plant with 36 percent efficiency in Europe, two of these SCC5-8000H 1S will generate 4.2 million tonnes less of the number one greenhouse gas, CO_2, per year. “This plant,” says Lothar Balling, Vice President of the GT Solution business in Siemens Energy, “is a key milestone to reduce CO_2 emissions and allows renewable energy to be integrated more easily into the grid due to its outstanding flexibility.”

Although Irsching 4 is aimed at base-load service, its combined cycle configuration (the SCC5-8000H 1S, see sidebar page 23) can easily handle 250 high-load start-ups and shutdowns per year in 30 minutes, notes Lothar Balling. “Especially in Europe, which is aiming for 20–30 percent renewable electricity by 2020, this kind of flexibility will be critical to our supply security – notably at times when the wind does not blow and the sun does not shine. We will need gas-fired units with maximum efficiency, minimal emissions, and fast start-up times.” During commissioning, a start-up time of less than 30 minutes to full load was demonstrated in addition to other world-class flexibility features.

Blades of More Than Steel

In order to achieve such extraordinary performance, Irsching’s plant must withstand operating conditions that are, well, extraordinary. One is a natural consequence of the unit’s record-size fins: The biggest blade wheel in the gas turbine sports a flow surface of 12.5 square meters. When spinning at 50 revolutions per second, they are pulled by several hundred tonnes of centrifugal force; under these circumstances, each cubic centimeter of each blade weighs some 70 kilos.

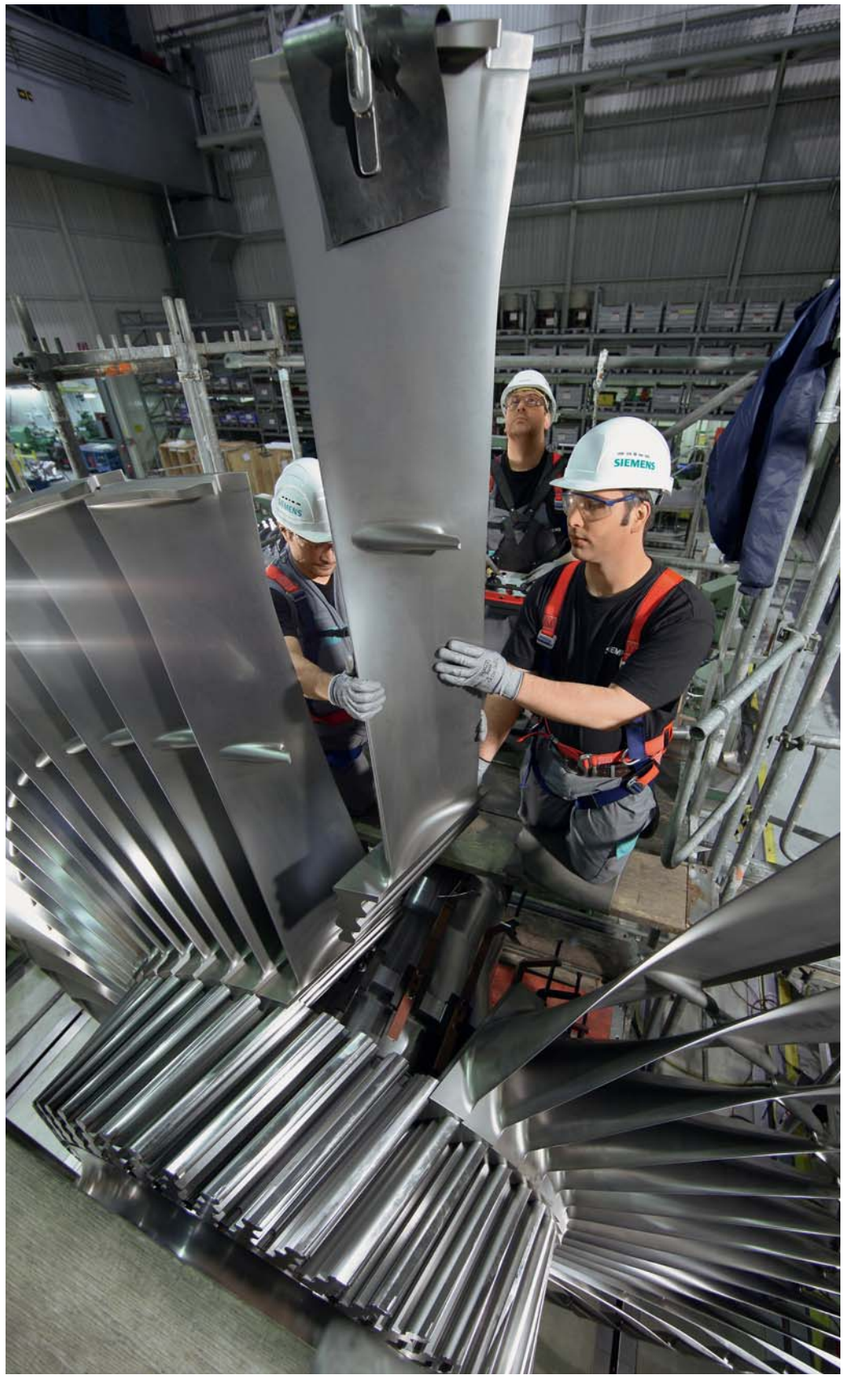
Even when composed of specialized nickel alloys, blades made by conventional casting – molten metal poured into a mould and cooled to a hard shape – are not capable of withstanding this stress. So Siemens’ scientists created an alternative manufacturing process. They engineered a proprietary chilling process that “grows” each blade as a so-called directional solidified crystal of metal, also making sure that each crystal is aligned in the direction of the centrifugal force. Because there are no longitudinal joins in the crystalline material, there is no predetermined breaking point.

Then there is the matter of efficiency. To get more bang from the burn, Siemens designers increased the

airflow, the pressure, and the temperature that flow through the gas turbine. This is a welcome effect to the extent that higher temperatures bring greater efficiency. It may have adverse effects, however, in that metal components can withstand only so much warmth. “It’s tricky when you send up to 1,500°C gas across metal turbine blades,” says Willibald Fischer, Program Director of the SGT-8000H series. “At 950°C, surfaces of conventional blades begin to glow red, and if things get any hotter, the material begins to lose its stability and oxidize.” In layman’s speak: If it gets too hot, a conventional blade starts to disintegrate. To prevent this from happening, blades on the SGT-8000H series gas turbine are built with two special jackets. First comes a thin coating of exotic metals: a pinch of rhenium added to a mixture of cobalt, nickel, chromium, aluminum, and yttrium. Without it, the nickel alloy blade would survive less hours at maximum operating temperatures before succumbing to oxidation. With it, by contrast, the blade can spin on up to 25,000 hours without service. The exotic coating also acts as glue for the second jacket, a ceramic layer that insulates the underlying metal.

In addition to the jackets that resist heat and wear, the blades are cooled actively in two ways. The hollow insides of the blades are bathed with lower-temperature air pumped by the compressor, and at their very front (the hottest part), they have fine holes from which air streams across the blades as a protective heat shield. All told, the composite system reduces surface temperature on the first row of blades from more than 1,400°C to around 950°C.

Irsching’s second efficiency trick is to fit the turbine in its shell like a hand in a glove. Thanks to three-dimensional design and another innovation, the so-called horizontal clearance optimization, where the rotor is shifted by hydraulics by some millimeters, the blade edges nearly – but not quite – scrape the inner walls. By keeping their headspace down to millimeters, waste is minimized. Almost all the gas passes across the blades and is converted to power.



The 16-square-meter titanium steam turbine blades of the SST5-5000 low-pressure rotor are assembled by Siemens engineers.

Photo: Siemens

Finally, Irsching performs a crowning efficiency. After the gas turbine extracts its mechanical power, heat is wrung out of the over 620°C exhaust gas by a Benson boiler designed to generate high temperature, and high-pressure steam for the 600°C steam turbine. This finishing touch adds another 200 MW to the electrical output while also raising overall efficiency from 40 percent in simple cycle operation to the final mark above 60 percent in combined cycle operation.

Bigger Is Better, and Better Is Better

Those who take a flip-the-switch-and-forget-it attitude towards electricity might be bored or baffled by Irsching’s high technology. Still, they have another good reason to be interested: Irsching and its SCC5-8000H 1S plant, which is now commercially available (see sidebar), save serious amounts of money.

Having one 16-square-meter highly innovative titanium turbine instead of two 8-square-meter ones in the steam turbine exhaust means less capital must be expended in terms of space, piping, and infrastructure. High efficiency also means less gas must be fed in to produce more power. “The price per MW of output, and the efficiency, correlate to the size of the plant,” says Balling. “In other words, the bigger it is, the more economical it will be, as long as it is as flexible as ours.” He notes that in 1990, the largest gas turbine produced about 150 MW, and, in conjunction with a 75-MW steam turbine, had an efficiency of only about 52 percent: “Since then, we have more than doubled the unit output and increased the efficiency by nearly 20 percent.”

One final beneficiary is the environment. Higher efficiency also means fewer emissions per kWh, and not just of CO_2, but also of particles, nitrogen oxides, carbon monoxide, and greenhouse gases nitrous oxide and methane.

All of these are details to be savored by electricity insiders. At commissioning time, the experts will be nodding. For the rest of us, there is a simpler way to summarize the exceptional nature of Irsching 4: When it comes to power, economics, flexibility, and fuel economy, it is a world record holder.

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Initiated in Irsching – Tomorrow’s Turbine Is Ready Today

First it set world records; now it is ready for commercial operation. The SGT-8000H series comes at 50 Hz either as a 375-MW simple cycle gas turbine or as a 570-MW combined cycle plant. In simple cycle operation, its efficiency is 40 percent; in combined cycle mode, it is over 60 percent under nominal rating. A 60-Hz version of similar efficiency will also be ready commercially for all customers later this year, after completing testing in Berlin.

“At Irsching, we’ve proven commercially the prototypes for the gas turbine, the 600°C Siemens Benson boiler, the 16-square-meter titanium steam turbine – all in combination,” comments Wolfgang Winter, the Siemens General Project Manager who oversaw construction. “They work together as we hoped; this really is a world record setter.”

The 60-Hz version, dubbed the SGT6-8000H, has already convinced two further buyers. At the South Korean site of Bugok, GS Electric Power & Services will connect its SCC6-8000H 1S 400-MW combined cycle power plant to the grid in mid-2013. CEO Lee Wan-Kyoung says the investment demonstrates GS’s great regard for efficiency and environmental-friendliness. Also on the books is Florida Power & Light, which during 2013–2014 will commission six 60-Hz version gas turbines to refurbish existing power plants at Riviera Beach and Cape Canaveral. Clearly, this retrofit will help to reduce global warming. According to FPL Executive Vice President Tony Rodriguez, the revamp will slash the units’ carbon emissions in half.

Further Information

www.siemens.com/energy