After assembly at Siemens' gas turbine plant in Berlin (above), the world's largest gas turbine hits the road. Bottom: The turbine arrives on a flatbed trailer at its destination.

Unmatched Efficiency

The world's largest turbine, with an output of 340 megawatts, will enter trial service in November 2007. In combination with a downstream steam turbine, it will help ensure that a new combined cycle power plant achieves a record-breaking efficiency of more than 60 percent when it goes into operation in 2011.

Residents of the town of Irsching in Bavaria, came out in droves this year to witness the traditional raising of their white and blue maypole. Three weeks later, they appeared in droves again — this time out of concern for the pole, as an oversized trailer had shown up carrying a new turbine for the town's power plant. The residents were worried that the turbine, which measured 13 meters in length, five meters in height, and weighed 444 tons, could pose a threat to their beloved maypole. This was not the case, however; specialists supervising the transport were actually more concerned about a bridge at the entrance to the town, which they renovated as a precautionary measure prior to the turbine's arrival.

The world's largest turbine, which was built at Siemens' Power Generation (PG) plant in Berlin, traveled 1,500 kilometers to get to Irsching — initially by water along the Havel river, various canals, the Rhine, and the Main. It then went down the Main-Danube Canal to Kelheim, where it was loaded onto a truck for the final 40 kilometers. This odyssey was undertaken because the only way to truly test such a large and powerful turbine is to put it into operation at a power plant. "It was a nice coincidence that the energy company E.ON was planning to expand the power station in Irsching," says Hans-Otto Rohwer, PG project manager in Irsching.

Siemens will now build a combined cycle plant at the Bavarian facility (Block 5) for E.ON Kraftwerke GmbH. Scheduled for completion in 2009, the plant will house two small gas turbines and a steam turbine. Siemens will also build the plant's new Block 4, where the giant turbine will be installed. The new turbine's output of 340 megawatts, which equals that of 13 jumbo jet engines, is enough to supply power to the population of a city the size of Hamburg.

"Block 4 is our project at the moment," says Rohwer. Siemens will use the existing infrastructure here, purchase gas from E.ON-Ruhrgas, and sell the electricity it produces at the plant. That's not that important now, however, as the turbine first needs to be tested over the next 18 months. To this end, the unit has been equipped with 3,000 sensors that measure just about everything modern technology can register — from temperature and pressure to mechanical stress and material strain. If a component is defective, or fails, computers linked to the sensors call attention to the problem immediately. The component will then be removed, replaced, or reworked.

Most of the measuring technology is hidden; the thing that stands out at the facility is a section of 21 office trailers housing the measurement stations. The trailers look tiny next to the turbine hall, which is 30 meters high. Despite its massive size, the new facility's metal facade makes it seem light and modern compared to the plant's three old concrete towers from the 1960s and '70s, each of which is 200 meters high. "The hall is still a long way from finished," says Rohwer, as he points to a big hole in the floor between the turbine and generator. "This is where we're going to install the oil systems to keep all movable parts of the shaft assembly lubricated. This is also where most of the smokestack, nearly all the electrical equipment, and the gas tanks will be located."

Efficiency Record. Rohwer points to an opening in one of the walls and explains that it is the connection to the air intake unit, which will draw in fresh air from the outside. Equipped with a special housing, filters, and sound absorbers, the unit will channel in 800 kilograms of air per second when the facility operates at full capacity — an amount that would exhaust the air inside the hall in just a few minutes. But it will be worth the effort because the gas turbine and a downstream steam turbine will set a new world record with an efficiency rating of over 60 percent, two percentage points higher than the previous titleholder, the Mainz-Wiesbaden power plant. Relatively speaking, therefore, less fuel will be burned and 40,000 tons less carbon dioxide (CO_2) per year will be emitted into the atmosphere than would be the case with the Mainz-Wiesbaden plant. And compared to the average coal-fired plant, which has an efficiency of 42 percent, the new facility in Irsching will emit around 2.3 million tons less CO_2 per year, while producing the same amount of electricity.

There will still be plenty of work to do even after the plant has been built, as technicians will have to test all systems to ensure that the gas lines are pressure-tight, electrical cables are properly secured, and all valves open and close quickly and reliably. It's like a final check before a space mission — and the countdown is now under way, with ignition scheduled for mid-December, 2007.

There's good reason for Siemens' decision to use one giant turbine rather than the two smaller ones E.ON will put into operation next door. "The price per megawatt (MW) of output and efficiency correlate with the size of the turbine — in other words, the bigger it is, the more economical it will be," explains Willibald Fischer, who is responsible for development of the 8000H turbine family. "In 1990, the largest gas turbine produced 150 MW, and, in conjunction with a 75-MW steam turbine, had an efficiency of 52 percent. Our gas turbine has an output of 340 MW. In combination with a 190-MW steam turbine it utilizes more than 60 percent of the energy content of the gas fuel."

Engineers at PG overcame two challenges while designing the turbine. They increased the amount of air and combustion gases that flow through the turbine each second, which causes output to rise more than the losses in the turbine, and they raised the temperature of the combustion gases, which increases efficiency. "It's tricky when you send gas heated to 1,200 to 1,500 degrees Celsius across metal turbine blades," says Fischer. "That's because the highest temperature the blade surfaces are allowed to be exposed to is 950 degrees, at which point they begin to glow red. If it gets any hotter, the material begins to lose its stability and oxidizes."

The turbine can produce enough electricity to supply a city the size of Hamburg.

Weighing in at 444 tons, the world's largest turbine is carefully positioned.

Ceramic Coating. Siemens engineers have been creative in tackling this problem. One thing they did was lower the heat transfer from the combustion gas to the metal by applying a protective thermal coating consisting of two layers: a 300-micrometer-thick undercoating directly on the metal and a thin ceramic layer on top of that, which provides heat insulation (see p. 50). The blades are also actively cooled, as they are hollow inside and are exposed to cool airflows generated by the compressor. The blades at the very front (the hottest part of the turbine) also have fine holes, from which air is released that then flows across the blades, covering them with a thin insulating film, like a protective shield.

As turbine blades spin, massive centrifugal forces come into play. The end of each blade is exposed to a maximum force of 10,000 times the earth's gravitational pull, which is the equivalent of each cubic centimeter of such a blade weighing as much as an adult human being.

The blades are made of a nickel alloy. These used to be cast and then left to harden. Later, crystallites were made to grow in the same direction as the centrifugal forces. But now the blades on the giant turbine in Irsching contain alloys that have mostly been grown as single crystals through the utilization of special cooling processes. They are therefore extremely resistant to breaking, as there are no longer any grain boundaries between the crystallites in the alloy that can rupture.

Engineers also optimized the shape of the blades with the help of 3D simulation programs, whereby the edges were designed to keep the gap between the blades and the turbine wall as small as possible. As a result, practically all the gas passes across the blades and is utilized. The blade-wall gap is made even smaller due to the turbine's operation in a cone. This means that the shaft can be shifted several millimeters during operation until the blades nearly touch the housing — a practice known as "hydraulic gap optimization."

Trial Run. Each off the measures mentioned above produces only a fractional increase in efficiency or output. But taken together they add up to a new record. Whether or not everything works as planned will be revealed by the 18-month trial period that will begin in November 2007. If preliminary test results are satisfactory, engineers will sign off on the new mega-turbine in August 2008, allowing Siemens to begin marketing it.

After successful completion of all tests in mid-2009, things will quiet down in Irsching. The turbine will then be overhauled and disassembled, and all of its components will be thoroughly examined. If everything is found to be in order, the unit will be reassembled minus its specialized measuring equipment.

During the overhaul, engineers will install an additional steam turbine on the shaft at the end of the generator. The turbine will make use of the generator's 600-degrees-Celsius gas to generate steam in a heat exchanger. Only through this combined cycle process can the energy in the gas be so effectively exploited as to achieve the record efficiency of 60 percent.

Conventional gas turbine power plants are generally pure peak-load facilities that can be turned on very quickly. But the Irsching plant is simply too good for that. "If the gas turbine proves itself during the trial period, we'll assume control of the plant in 2011," says Alfred Beck from E.ON Kraftwerke GmbH. "It's high efficiency will make it profitable for use in medium load operations, despite slightly higher gas prices."

The facility will then generate electricity for between 3,000 and 7,000 hours each year, and will definitely be a superlative power plant.

Bernhard Gerl