Electric and Industrial Process Heat Production using CCGT Technology

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I.C.R.A. Alterswil, Switzerland
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My involvement in thermal power generation units in solar energy, particularly the SEPP project, has been discussed on various occasions. The background to this is twofold,

(1) experience with radio-astronomy and its associated dish technology (and its obvious computer control for guiding),
(2) work in gas turbine technology, primarily within a special section, the closed-cycle gas turbine.

Why Closed Cycle?

Much higher electric and total efficiency, smaller engines, usable waste heat energy for community heating or industrial process heat and an energy transport medium that is 20x as efficient as air: helium. Helium, an inert gas, when applied in the gas cooled helium reactor as working medium, cannot become radioactive - helium is an inert gas!

We need to explore some background information in order to understand where everything is coming from. I shall start with an episode at the very end of a technology process spanning more than 40 years.

Back in 1986, Prof. Dr.-Ing. Karl Bammert (more below) asked me to join him in a meeting with the head of Fuji Heavy Industries and a group of high ranking Japanese officials in a remote dwelling outside Houston, Texas. We were attending the ASME (American Society of Mechanical Engineering) conference with lectures on our subject, long-term CCGT experience and its advantages for power generation in Germany. The Japanese wanted Professor Bammert to consult for them to bring Closed-Cycle Gas Turbine technology to Japan - they would do the work, he would look it over and tell them where they went wrong. He only was to fill in the number on the bottom right hand side on the cheque. And Karl refused for reasons of patriotism. I, on the other hand would not have refused. But, I guess you have to read on.

Let me elaborate to make clear why I see this as a special opportunity.

Short Conclusion

Germany's power generation has traditionally been based on coal (Ruhrkohle) and later gas as natural primary energy. From the mid-fifties onward, nuclear power became a priority (mainly through Preussen Elektra and RWE) and many water reactors along the Westinghouse principle were built. As nuclear power generation evolved and its problems with the types of reactors used (Westinghouse and later a fast breeder reactor) and their associated waste problem became clear, the government asked industry and science to look for alternatives in the nuclear field. This work started as early as about 1957.

The helium-cooled reactor coupled to a helium closed cycle gas turbine was an answer - absolute control over the nuclear operation. Production of fuel material (small graphite balls containing enriched Uranium 235) in Germany, waste no problem. Herr Schröder has sold the plant used for uranium enrichment in Germany to China. One such gas-cooled nuclear

reactor was built and operated in Hamm-Uentrup, North-Rhine Westphalia, its power generation unit, a closed-cycle helium gas turbine operated separately in the Ruhrgebiet, in Oberhausen, where Prof. Gerhard Deuster, head of EVO, had operated successfully a closed-cycle gas turbine (air) for the city utility company for more than 25 years. The Research and Development Ministry's Sonder Forschungs Bereich 17 (Special Scientific Area) used it as a case study for the next (this) millennium electricity production. I was asked to sit on the governmental board together with the users, builders, and developers of this technology for Germany's future electric power generation.

It all fell apart when the Green party changed the public and political thinking away from nuclear power. The word 'nuclear' by itself became a no-no with most of the politicians involved not really understanding what it was all about (and still not so today).

Background and Technology

For more than 30 years, a group of top German engineers and builders (coming from GHH and MAN) had built and used closed-cycle gas turbines (CCGT) in community electric power generation systems from small units of 18 MW to the then normal 300MW size for larger plants. De-centralization was the code word: *spread the generation of electric power into many smaller units and use a network of them throughout the country*. Germany went through the RAF terrorists back in the nineteen seventies and knew what can happen when they cut power lines à la USA.

One key person was the progenitor and co-inventor of the closed cycle gas turbine (CCGT): Professor Dr.-Ing. Karl Bammert, at first head engineer at GHH-MAN Gas Turbine Technology Division in Oberhausen-Sterkrade, then professor and head of the Department of Fluid Machinery at the University of Hannover.

Karl and I became good friends in 1974 (he died some ten years ago at age 88 chasing his doctorate students still up the Monte Rosa as a ski instructor - I am not joking!) when I offered him a solution for a solar receiver problem that he had been pondering and not been able to solve for years. I did all the equations in one night in my hotel room in Albuquerque - it was obvious for someone with an astronomical background. It had to do with the even distribution of impinging solar radiation and its associated tube loads on the tube material (Incoloy and Inconel) along the heater tubes in a heater (receiver) for a 300 $MW_{thermal}$ solar power plant. The solution was a so-called RADIS Cone, the RAdiation DIStribution cone, as it became known in circles around this topic. Its shape was derived from a well-known dual shape prominent with the female human species. Few people, I suppose, ever developed mathematical equations about radiation distribution around those bodily features, but this was the essence of the solution. The question is, did I have this shape in mind when looking for the solution to Karl's problem, or did it evolve while working on the problem. I cannot remember anymore.

Karl had a total of 355 doctorate students, many of whom became professors and heads of industry in Germany during their career. Their thesis mainly revolved around the theme of the application and development of the closed cycle gas turbine and its associated problem areas that needed further research. One of these late students was yours truly. I introduced Karl to solar electric power generation for larger scale solar thermal power plants based on radio-astronomical dish technology.

Prof. Dr.-Ing. Gerhard Deuster was head of the EVO - Energieversorgung and Stadtwerke (City Works and Utility Company) Oberhausen and used two large closed cycle gas turbines in the city's power generation. I had an office in the EVO building for 5 years when I optimised the power generation network for the Ruhr area for Gerhard. It was the first computer-controlled network that encompassed electric power generation, electricity users

and grid-connected gas suppliers and waste heat users in the Ruhrgebiet. Gerhard is retired now and we keep a good contact. He is lecturing occasionally on the CCGT theme.

Consul Josef Rurik (the family of the founders of Russia way back when) was the Technical Vorstand (director) of GHH; under him, Karl was head engineer before Mr. Rurik arranged the professorship for Karl in Hannover and Gerhard was a free-lance inspector of turbine technology. This is how the three met back in the mid-fifties. I am still very good friends with Consul Rurik and see him regularly (he is 84 years now and fit - just like Karl. He does not chase students, he walks by himself - miles and miles in the Carpathian mountains). He is a fatherly friend to me and was head of my company back in the early eighties when he retired from GHH and could not quit working.

The three of us, Consul Rurik, Gerhard Deuster and I still maintain connections to some of the doctorate students of Karl's. One of them is the head of Thyssen-Krupp now. The two gentlemen have the expertise and know-how when it comes to building and operating closed-cycle gas turbines.

Late in Karl's career, in the nineteen eighties, Karl and I (and Gerhard at times) toured the conference scene through the ASME - American Society of Mechanical Engineers Gas Turbine Section. We lectured on the long-term experience of the six CCGT's (Closed- Cycle Gas Turbines) running in Germany and their advantages and improvements and new applications - solar energy power generation, with me swinging far out proposing a CCGT running on helium in space to power a large space station.

From 1974 to about 1986 I have been associated on a business and personal level with the inventors and the people who have applied closed-cycle gas turbine technology to electric power generation on a large scale in the German power generation scene. I have had the joyful experience of receiving private lectures on the intimate workings of fluid mechanics in gas turbines from Karl, a man for whom physics was his alter ego. I have never experienced a more profound knowledge and intimacy with physics than through Karl's mind. It was an unbelievable experience. Gerhard would know all the tricks of running a CCGT over the more than 30 years he used them to generate power for the cities of Oberhausen and Sterkrade and Consul Rurik was the one who could manage the building of the rather complicated and delicate machinery in an age without computers checking blades and bearing run-outs. I have spent countless hours inside the giant heaters of the gas turbines, the ones that were fired with coal dust and gas, measuring tube failures, and working on large-scale computer control mechanisms for the power plants and industrial users.

The top development was the Helium CCGT in Oberhausen, installed in 1974. It marked the stepping-stone for a new generation of highly efficient and cost-effective gas turbines. During the first year we had a small helium leak at the seals of the high power section of the turbine (about 4 kg per day) and maintenance always was a rather giggly affair with the helium in the air around the turbine. But we laughed a lot also outside the machine section, without the aid of helium.

When Karl went to his vacation apartment in Zermatt, my wife Petra and I accompanied him. He skied the mountains, I corrected a students' thesis and prepared his presentation for the next conference whilst sitting on the Sunnega or Kleine Matterhorn or the Gornergrat restaurant terrace having a good glass of wine.

CCGT technology has not been followed up. Boeing built one 3 MW unit for a submarine but could not really get it to run successfully. You cannot efficiently build small CCGTs - the blades in the high power section get too small to be efficient. Karl laughed at the project and said he would find it inappropriate to even talk to the guy who designed it - he should have done his homework in fluid dynamics first before trying to build modern machinery. Life was not easy on Karl's side. He was very demanding. But he was always right in his criticism.

One major application of CCGT technology is certainly the combined electric and process heat application that can bring a plant's efficiency to over 62% - unheard of in conventional power generation where they fight about 1/10 of a percentage point at 44%. In space, the efficiency of a Helium CCGT shoots up to 92% - the Carnot cycle is the answer: low input temperature versus a high output temperature gives the efficiency equation.

In power generation, the use of a helium-cooled nuclear reactor in conjunction with a Helium CCGT is the premium solution. No doubt about it. It makes the simplest system (this, of course, is a rhetoric misnomer - no nuclear power plant is simple) with one only cooling cycle medium, Helium, that passes right from around the graphite balls (about 6 cm in diameter - very many of them - poured into the nuclear reactor cylinder) in the containment vessel to the CCGT and that's it. No secondary or tertiary cooling cycles. Add more Helium, and the nuclear reaction goes down, with less Helium, the temperature rises. The 300 MW Helium Turbine at Oberhausen measures about 4 m by 3 m at the high-power section. The Gas Cooled Reactor in Hamm-Uentrup ran beautifully for years. The second step would have been to mate the Hamm-Uentrup reactor with the Oberhausen Helium turbine. The folks at Hamm-Uentrup had the same problems at first with Helium leakage – it permeates anything given enough time. Thus is the power of an inert gas at low atomic proton levels.

The 25 years of the Sonderforschungsbereich 17 were successfully closed with an excellent report on everybody's work. It showed that CCGT technology coupled to the Gas-Cooled Helium Reactor was not only viable but could be produced in industrial quantities and economically. The efficiency – and thus economy - was highly superior to present day system technology by its very basic physics approach, the Carnot cycle and knowledge about gas chemistry.

As is always the case with long-term special scientific studies, it solved many ancillary problems as a by-product that found their way as industrial solutions today. The way into a bright and economic future for Germany's energy problems seemed paved for the next generations until a nuclear fission reactor was to come into being some time after the year 2050.

Then the Green Party with the SPD came to power in Germany and knew everything better and a superior technology with more than 150'000 hours of running experience on a commercial level was doomed and dropped. And they keep searching for the solution to economical and ecological energy production by shutting off nuclear power stations to replace them with coal and gas fired plants. What a farce for CO_2 output and the world ecology and Kioto protocols! And we deprive our children of the natural resources of this planet by burning more oil, more coal and gas.