Light Industrial & Marine (I&M) Gas Turbines: Design and Development

A number of the light industrial and marine gas turbine machines and engines in design and development do not warrant inclusion as full reports. (Light machines/engines have a power output of less than 15,000 hp, or 11,185 kW.) These gas turbine programs are summarized below.

A parallel report is provided in this book for heavy gas turbine machines and engines having a power output of 15,000 hp (11,185 kW) and larger.

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GE LM120. In 1989, reports from Washington, DC, indicated that the U.S. Marine Corps was looking for a new generation of tracked amphibious assault vehicles powered by gas turbine engines while at sea and diesel or rotary engines while on land. The demonstrator used a General Electric Company (USA) GE Aircraft Engines LM120 gas turbine, a derivative of the T700 turboshaft engines used in the Sikorsky H-60 series.

The LM120 had a continuous-duty rating of 2,000 bhp (1.49 MW) at ISO conditions and an average heat rate of 8,200 Btu/hp-hr, equivalent to about 31 percent efficiency. The demonstrator engine is rated at 1,560 bhp for operations at 37.8°C. This engine never saw production and is no longer included in any GE reference material. This entry will be deleted next year.

Kawasaki CGT302. The Kawasaki Heavy Industries (KHI) CGT302 is a recuperated twin-shaft microturbine intended for cogeneration duty, rated at about 300 kW. The machine was designed for a wide range of partially loaded conditions. Much of the effort to develop a ceramic gas turbine in Japan has been sponsored by the Japanese government.

The KHI CGT302 advances the use of ceramics and has a conventional components layout, a blisk-type turbine rotor, and a triple casing to minimize heat radiation loss. Ceramic wave rings and Si_3N_4 coil springs are employed.

Part of the Kawasaki CGT302 effort was done under the New Sunshine Project, a Japanese national project for developing new energy, energy-saving, and environmental protection technologies. In 1988, the New Energy and Industrial Technology Development Organization (NEDO) started the Ceramic Gas Turbine (CGT) project. The effort, which was originally expected to take nine years, was extended by two years to develop three different types of CGTs: the CGT301, CGT302, and CGT303. That work was done under a contract with the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry (MITI), since renamed the Ministry of Economy, Trade and Industry (METI). The development objective was to achieve a 42 percent thermal efficiency (lower heating value) at 1,350°C turbine inlet temperature (TIT).

In terms of ceramic components, other goals of the 300-kW CGT program were a minimum guaranteed strength of 400 MPa at a temperature of 1,500°C, a Weibull modulus (Reference) of at least 20 at a temperature of 1,500°C, and a fracture toughness at room temperature of at least 15 MPam1/2.

Paralleling the CGT302 effort, which was originated by the MITI/NEDO as part of the 300-kW CGT program, is the development of a single-shaft CGT with recuperator, also intended for cogeneration. The machine is designated the CGT301. Also being developed is the CGT303, a two-shaft CGT with recuperator; it is intended for mobile power. Fewer than five CGT302s were fabricated and the project now appears defunct.

Niigata RGT3R. The Niigata Power Systems Company (Tokyo, Japan) RGT3R is a 300-kW electric power output recuperated-cycle gas turbine machine. The machine is a single-shaft mini-turbine that has a single-stage centrifugal compressor and a radial turbine with a liquid-fuel dry low emissions (DLE) combustor. It uses a two-stage, parallel, premixed, prevaporized lean burn system implemented in a simple configuration developed through collaboration between NAL (the National Aerospace Laboratory of Japan in Tokyo) and Niigata Power Systems Company Ltd.

Testing of the first prototype engine, a simple-cycle RGT3R with a diffusion combustor, began in May 2002. Testing of a recuperated-cycle RGT3R began in August 2002. For that phase of testing, a diffusion combustor modified for the recuperated cycle was mounted on the RGT3R. In the third phase of

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testing, which began in January 2003, Niigata began operating the recuperated-cycle RGT3R equipped with a liquid fuel DLE. The machine became ready for commercial production in 2004.

In mid- to late 2002, Ishikawajima-Harima Heavy Industries Company Ltd signed a sponsorship contract with the trustees in the bankruptcy of Niigata Engineering Company Ltd for the business conducted by Niigata Engineering. IHI continued discussions with the Development Bank of Japan (DBJ) on investment in the business while preparing to establish new companies based on the reorganization plan.

The Tokyo District Court approved the reorganization plan in December 2002. Based on that approval, IHI and DBJ jointly established two companies, one of which was Niigata Power Systems Company Ltd, to take over the businesses of Niigata Engineering on February 3, 2003. Niigata Power Systems Company is now owned by IHI (70 percent of the capital invested) and DBJ (30 percent).

At least one RGT3R was fabricated for testing and proof-of-concept, but no further development has taken place.

Optimal Radial Turbine BV OD5. The firm Optimal Radial Turbine BV (also referred to as OPRA Optimal Radial Turbine BV) was established in Hengelo, the Netherlands, in 1991 by the turbine developer Jan Mowill and his Norwegian company Mowill Turbinmotor A/S. OPRA BV has over 30 years of experience developing and marketing radial turbine engines for the former Kongsberg Turbine Division. Engine development is supported by the Dutch Agency for Energy and Environment (NOVEM). The Annular Low Emissions Combustor (ALEC) was codeveloped with NV Nederlandse Gasunie in an effort begun in 1990. In 1993, VZLU Turbo Motor s.r.o. (Prague, Czech Republic) became a 30 percent partner in the engine program, responsible for development and manufacture of the LP module.

The smaller of OPRA's efforts is the OD5, a novel twin-spool, all-radial turbine engine in the 450- to 500-kW power class; the machine effort is part of a joint program with Daihatsu Manufacturing Company of Japan. The first machine in the series is rated at 487 kW simple cycle and features a two-shaft all-radial configuration with an HP radial turbine driving the HP compressor and generator or other driven machine. The HP turbine has an expansion ratio of 1:7, while the remaining energy is expanded into the LP turbine, which drives only the LP compressor. The LP centrifugal compressor has a pressure ratio of 3:1; the HP centrifugal compressor has a ratio of 5:1.

Preliminary specifications of the 500 A2 include a mass flow of 2.36 kg/sec, a pressure ratio of 14.55:1, an exhaust temperature of 477°C, and a shaft efficiency of 29 percent. Major dimensions are as follows: length, 1,740mm; width, 910mm; and height, 677mm. In 1993, the first phase of the engine program was completed with the testing of the HP demonstrator module and the ALEC; testing was done at VZLU in Prague.

While the OP16 has entered production and is the subject of a report in this service, the OD5 appears to be defunct.

Solar Mercury 50. The Solar Mercury 50 (also known simply as the Mercury) was developed in cooperation with the U.S. Department of Energy as part of its Advanced Turbine Systems (ATS) program. The machine effort was intended to achieve a thermal efficiency of more than 40 percent. Other goals were to produce 21st century gas turbines and systems that would be more efficient, cleaner, and less expensive to operate than today's turbines. The program's goals centered on a reduction of NOx to a level of 9 ppmv or less, improved efficiency, and a reduction in the busbar cost of power.

The Mercury has 10 axial compressor stages, two reaction-type gas-producer turbine stages, and one reaction-type power turbine stage. The early Mercury 50 machine was rated at 4,200-kWe continuous output for generation duty, 4,600 kWe for intermediate duty, and 4,800 kWe for peaking applications. The early Mercury 50 generator set measures 9.8 meters in length; it weighs 43,100 pounds.

In January 2000, Solar informed power developers that it would not provide quotes on Mercury 50 machines until further notice. Among the reasons believed to be behind that announcement were technical and production cost problems. Fewer than 20 Mercury 50 machines had been fabricated when the program was halted.

At the 2003 Power Gen International Conference, Solar Turbines announced the commercialization of its Mercury 50 Recuperated Gas Turbine. Solar reported that this addition to its product line represented a technological breakthrough in recuperative gas turbine technology, with many environmental, operational, economic, and siting advantages.

Since the Mercury 50's initial launch, Solar has developed a series of product improvements that have now been incorporated into the engine, recuperator, and package to address issues exhibited during the field evaluation program.

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As of December 2003, the 4-MW-class Mercury 50 had completed more than 40,000 hours of operating experience at field evaluation sites that provided Solar with data regarding the operation of the generator sets over a variety of conditions, including a range of ambient temperatures, different fuel properties, and numerous customer-driven operating scenarios.

Solar made the decision to invest in the success of the Mercury 50 program, and addressed the issues surrounding the engine through a continued development program. The most significant improvements to the product have acted to extend recuperator durability. Since the initial field evaluation, the recuperator material has been upgraded and structural design integrity has been enhanced; also, performance improvements were made in the compressor and turbine sections. The Mercury 50 has been reintroduced with a nominal power rating of 4,600 kW with a heat rate of 8,863 Btu/kW-hr (9,351 kJ/kWh). It has an exhaust temperature of 705°F (373°C), with exhaust flow of 141,430 lb/hr and an efficiency of 38.5 percent.

The Mercury 50's innovative Ultra Lean Premix combustion system utilizes Solar's next-generation ULP combustion system. The Mercury 50 is available with a 5-ppmv NOx guarantee, with the CO and UHC guarantees both at the 10-ppm level.

The performance characteristics of the Mercury 50 allow it to be employed in roles beyond traditional industrial cogeneration or combined heat and power (CHP) applications. The Mercury 50 is well suited for commercial CHP or building cooling, heating, and power (BCHP) applications where steam loads are less than 25,000 lb/hr (11,340 kg/hr) and where chilled or hot water is required. The Mercury 50 is also well suited for intermediate peaking applications such as economic dispatch for municipal utilities and rural electric cooperatives; for distributed generation applications such as utility grid support and shoulder management for municipal and rural electric cooperatives; and for load following.

Mercury 50 applications include Dell Children's Medical Center of central Texas, which in 2007 received a 4.6-MW gas turbine as part of a cogeneration system. The Veterans Administration Hospital in La Jolla, California, upgraded its two existing 1.2-MW Solar gas turbines in 2009 to a single 4.6-MW Mercury 50 gas turbine generator set.

In 2013, PEI Power Corporation purchased two Mercury 50 machines for a landfill gas power generating system at its Archbald Cogeneration plant in Pennsylvania.

Super Marine Gas Turbine (SMGT). In 1997, five Japanese gas turbine manufacturers (KHI, IHI, Daihatsu Diesel, Niigata Engineering, and Yanmar Diesel) joined in a six-year project to establish the Technological Research Association for Super Marine Gas Turbine (SMGT); the association is headquartered in Tokyo.

The SMGT was a 2.5- to 2.6-MW-class gas turbine designed primarily for use as a main engine for coastal shipping. Its design parameters include NOx emissions of less than 1g/kWh, a thermal efficiency in the 39-40 percent range, and the ability to burn Type A fuel oil.

The machine has a three-burner arrangement, a plate fin recuperator, and a compressor arrangement that includes an axial type for the LP stage and a radial type for the HP stage.

The power unit of the experimental unit is 2.2 meters in length and weighs 1,800 kilograms.

Phase 1. The following objectives were realized in a land-based test carried out at the end of FY02 (March 2003):

Thermal Efficiency: 38-40 percent (about the same level as a high-speed diesel engine, and the highest among the gas turbines of its class in daily use).

NOx Emissions: 1g/kWh at 200 ppmv (O_2 = 0%) or less (about one-tenth of the emissions from a high-speed diesel engine).

Fuel Type: A heavy use of oil, depending on availability at ports.

Phase 2. Based on the success of Phase 1, this phase aimed to raise product reliability to a level suitable for daily use as a marine engine. The endurance test was scheduled for completion at the end of FY04 (March 2005).

No references to this project have appeared since 2003 and the system appears to be defunct.

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Contractors

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