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INDUSTRIAL ADVANCED TURBINE SYSTEMS:

DEVELOPMENT & DEMONSTRATION

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Addendum to WBS 14400: Host Site Test & Evaluation – Mercury 50

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Solar Turbines
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ADVANCED TURBINE SYSTEMS PROGRAM

WBS 44100: Host Site Test & Evaluation - Mercury 50

Summary: Rochelle Municipal Utilities (RMU) was selected for the field evaluation site and placed an order for the first Mercury 50 generator set in November 1997. Field evaluation of the Mercury 50 package at Rochelle began in June 2000 and ran through December 2003. A total of 4,749 package hours were achieved on two generation 2-design engines. Engine Serial Number (ESN) 6 was installed in April 2000 and accumulated 2,324 hours and 267 starts until it was exchanged for ESN 7 in April 2001. ESN 7 ran until completion of the field evaluation period accumulating 2,426 hours and 292 starts. While the 4,749 hours of package operation falls short of the 8,000-hour goal, important lessons were learned at the Rochelle site that resulted in bringing a far superior generation 3 Mercury 50 package to commercialization. Among the issues raised and resolved were:

- Engine shaft stability
- Engine power and efficiency degradation
  - Air inlet Restrictions
  - Compressor Efficiency
  - Turbine Efficiency
  - Exhaust System Cracks/Leaks
- Recuperator Core Durability
- Cold Weather Operations
- Valve Actuator Reliability
- Remote Operation and Maintenance Support

Figure 1 Mercury 50 Installed at Rochelle Municipal Utilities

Details: Solar entertained discussions with a number of interested entities regarding the location of a host site for the 8,000 hour field demonstration of the ATS system in 1996. Solar's approach was to identify and develop an agreement with a host utility, which could assist in the location of one or more industrial sites for final selection by Solar, DOE and the host utility. Interested utilities included investor owned utilities as well as municipal utilities.

One of the sites located was Rochelle, IL Municipal Utility (RMU.) They were a potential host utility with focus on strengthening the service RMU provides to its industrial customers. Rochelle is located on a major interstate approximately 60 miles due west of Chicago. Rochelle is home to two very large cold storage facilities used as part of the distribution network of foods coming in by rail from all over the U.S. and then stored until called for by wholesale/retail supermarkets in the upper mid-west. Rochelle is also home to a Hormel processing plant that specializes in pork products.

Presentations were made to the General Manager of the utility and in a separate meeting to the Rochelle City Manager and the General Manager of the Utility. Discussions centered around the ATS Program, the Solar ATS product, the needs and requirements for the DOE Host Site and other field demonstration sites. The second meeting with representatives of Rochelle included an expansive tour of the utility infrastructure in place and under construction and the potential industrial host sites currently served by Rochelle. Rochelle Municipal Utilities (RMU) expressed serious interest in locating the DOE host site within the city of Rochelle, Illinois and was willing to purchase the unit.

Solar’s ATS Commercialization Manager made a presentation in late July 1997 with RMU and members of local industry in Rochelle, IL regarding the ATS program, Solar’s ATS product, and selection of the host site. Following continued strong interest, an August meeting was held in Rochelle with the GM of RMU and representatives of Hormel Foods.

A meeting was held in August 1997 with representatives of Duke Power/Duke Fluor Daniel in Houston during which Mercury 50 host site opportunities were discussed.

In September 1997, RMU’s General Manager and Solar’s Commercialization Manager made a joint presentation to DOE’s Steve Waslo, Pat Hoffman and Lisa Barnett, as well as to Solar’s ATS and Sales & Marketing personnel. They proposed that RMU locate the demonstration unit in its service area. All parties favorably received the presentation. A proposal was later sent to RMU.

Rochelle Municipal Utilities placed an order for the first Mercury 50 generator set in November 1997. The unit to be used in an intermediate duty, economic dispatch mode to reduce Rochelle's electric costs and to improve reliability to its industrial and commercial customers.

Based on the host site selection of WBS 71100, the design and construction process was initiated with a complete host site conversion plan for Rochelle. The Mercury 50 site was to be arranged within the existing facility. Existing equipment and site were audited for interface with the package systems. Fuel, switchgear, and water systems were sized to meet the configuration and load requirements.

The host site conversion and construction phase included the permit acquisition, site preparation, foundations, underground utilities installation, buildings, instrumentation installation, interconnection checkouts, commissioning procedures, and 24 hour site green-run.

The host site test plan included the defining of purpose, goal, and the expected results. Procedures for testing with the necessary instrumentation, safety, and environmental requirements were defined with the delineation of responsibilities.

The primary operating parameters for the power generation plant field test included power output and efficiency, performance sustainability, reliability, availability, maintainability, costs and durability.

The Rochelle package was turned over to the customer in May 2000 and began field evaluation. A formal commissioning ceremony was held on June 12, 2000 with DOE and Solar personnel in attendance. This unit completed 1700 hours and 215 starts by the end of 2000.

By March 2001, ESN 6 accumulated 2,324 hours with 267 starts and performance was down due to leaks in the turbine exhaust system and the recuperator. RMU anticipated running 24 hours per day starting May 1 and Solar agreed to replace the engine and recuperator. ESN 7 and recuperator #18 replaced ESN 6 and recuperator #9 in April 2001. Startup occurred on April 18, 2001.

ESN 6, removed from Rochelle, was disassembled and inspected. The compressor was very dirty, but otherwise in good shape. The bearings looked good and were sent to MRC for inspection. The exhaust collector had numerous cracks near the outlet flange that would account for some of the performance degradation.

The Rochelle recuperator and exhaust “rag joint” were inspected at TurboFab and found to be in poor condition. Badger representatives were invited to inspect the rag joint (-400) and discuss how improvements in the current design (-500) will prevent the noted damage. Recuperator #9 had numerous cracks including some at the ends of the air out duct that had not been observed before.

Site data taken from Rochelle in July 2001 for ESN 7 was analyzed and compared to acceptance test data and to site performance of the previous engine (ESN 6). The data indicated the engine was performing as expected based on engine acceptance testing. The data also indicated the engine was producing 2 to 4 % more power than ESN 6. The

site conditions, ambient temperature, and position of the ADV accounted for an apparent lower performance of the current engine.

ESN 7 operated on a daily basis throughout the summer of 2001 with some 24-hour-per-day operation on the weekends. The unit accumulated 741 hours and 54 starts before cool weather and competitive wholesale market power prices limited unit operation in early September.

ESN 7 operated sporadically through the fall and winter of 2001. The unit accumulated 947 hours and 89 starts by the end of February 2002. The unit failed to start on March 3, 2001 due to a stuck relief valve in sub-zero weather. The valve was cycled remotely and startup was achieved. During the week of March 25, 2002 the unit was dispatched several times as local temperatures dipped below freezing and starts were successful each time.

The unit exceeded 10,000 megawatt-hours produced on June 26, 2002. ESN 7-3 had 1,487 hours and 142 starts.

The Rochelle unit again operated in economic dispatch mode throughout the summer of 2002. ESN 7-3 had 1,917 hours and 184 starts at the end of September 2002.

Operation through the fall and winter of 2004 was again sporadic.

The unit returned to economic dispatch mode from the end of June 2003 through early September when ESN 7-3 had 2,367 hours and 274 starts. The Rochelle package had 4,690 hours and 541 starts.

ESN 7 ran occasionally until 12-31-03, the end of the contract, accumulating 2,426 hours and 292 starts. The Rochelle package hours totaled 4,749 with 559 starts.

Conclusion: The field evaluation at the Rochelle host site demonstrated the capability of the Mercury 50 and pointed out several areas that needed improvement. The experience resulted in bringing a far superior Mercury 50 package to commercialization. Among the issues raised and resolved were:

- Engine shaft stability
- Engine power and efficiency degradation
  - Air Inlet Restrictions
  - Compressor Efficiency
  - Turbine Efficiency
  - Exhaust System Cracks/Leaks
- Recuperator Core Durability
- Cold Weather Operations
- Valve Actuator Reliability
- Remote Operation and Maintenance Support

A benefit of running the evaluation at Rochelle was the opportunity to operate the Mercury 50 system over a wide range of climatic conditions. Lessons on how to start and run the unit in freezing weather was valuable. Testing the emissions capability of the recuperated cycle in widely varying ambient temperatures was another benefit. From sub-zero in winter to over 100^{o}F in summer, the unit was able to start, run and load while demonstrating stable emissions. Mercury 50 emission levels were verified to be well under local permit requirements during periodic state agency checks and the program goal of single-digit NOx emissions was consistently met.