THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

ETV Joint Verification Statement

TECHNOLOGY TYPE:	Gas-Fired Internal Combustion Engine Combined With Heat Recovery System
APPLICATION:	Distributed Electrical Power and Heat Generation Using Aisin Seiki Cogeneration Unit
TECHNOLOGY NAME:	Aisin Seiki 6.0 kW Natural Gas-Fired Cogeneration Unit
COMPANY:	Aisin Seiki Co., LTD.
ADDRESS:	Aichi, Japan
WEB ADDRESS:	www.aisin.com

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the purchase, design, distribution, financing, permitting, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups that consist of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates the performance of technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Greenhouse Gas Technology Center (GHG Center), one of six verification organizations under the ETV program, is operated by Southern Research Institute in cooperation with EPA's National Risk Management Research Laboratory. A technology of interest to GHG Center stakeholders is distributed generation (DG) sources, especially when they include combined heat and power (CHP) capabilities. The

improved efficiency of DG/CHP systems make them a viable complement to traditional power generation technologies.

The GHG Center collaborated with the New York State Energy Research and Development Authority (NYSERDA) to evaluate the performance of an Aisin Seiki G60 6.0 kilowatt (kW) natural gas fired engine cogeneration unit manufactured by Aisin Seiki Co., LTD in Aichi, Japan. The Aisin Seiki G60 is an internal combustion engine generator set capable of producing nominal 6 kW of electrical power with the potential to produce an additional 13 kW of heat. The G60 selected for this verification is owned by the manufacturer and operated at Hooligans Bar and Grille in Liverpool, New York. ECO Technology Solutions, LLC. (ECOTS) serves as Aisin's primary agent in the U.S. and manages the installation and operation of the Aisin system at Hooligans.

TECHNOLOGY DESCRIPTION

The following technology description is based on information provided by Aisin and ECOTS and does not represent verified information. The Aisin Seiki G60 6.0 kW natural gas fired engine cogeneration unit is a natural gas-fueled engine driven generator from which excess heat is recovered for use on-site. This technology provides a maximum 6.0 kW electrical output at 120v single phase in parallel with the utility supply. The engine is a water-cooled 4-cycle, 3-cylinder overhead valve unit that drives a synchronous generator. Some of the waste heat produced by the engine [approximately 46 thousand Btu per hour (MBtu/h)] is recovered from engine coolant and the exhaust gases and supplied to an indirect fired water heater and storage system to provide first stage water heating for the host site's hot water system. Heat transfer fluid is circulated through the Aisin heat recovery system by an external circulation pump to provide heat for use in the facility. Table S-1 summarizes the physical and electrical specifications for the unit.

Table S-1. Aisin Seiki G60 Specifications

(Source: Aisin Seiki Co., Ltd.)

Physical Specifications	Width	1,100 mm
	Depth	660 mm
	Height	1,500 mm
	Weight	465 kg
Electrical Specifications	Electrical Input	Interconnection of AC/DC conversion + inverter
	Electrical Output at Hooligans	6.0 kW, 240 V, single phase, 2-wire
	Engine Type	Water-cooled vertical 4-cycle 3-cylinder OHV
	Generator Type	Permanent magnet rotating-field type
	Rated Power Generating Efficiency	26.5%
	Rated Waste Heat Recovery Efficiency	59.5%

At Hooligans, the Aisin G60 is integrated into the facility's existing domestic hot water and electrical distribution systems. The output of the cogeneration unit is 120/240v, 60 Hz single phase. The restaurant has an 800 amp 120/208v three phase service. Installation of the Aisin G60 required the addition of a 120/240 to 120v isolation transformer in order for the restaurant service to properly accept the unit output. The connection was made to the phase with the highest normal load, so as to bring the load into greater balance.

As part of the control system, current transformers (CTs) are located on the neutral and the unit's connected phase. The output of these CTs are connected to the Aisin unit to monitor the power flow on the phase and neutral to provide signaling that prevents the unit from exporting power to the grid. This configuration causes all energy produced to be used on-site.

Prior to installation of the Aisin cogeneration unit, Hooligans used an 85 gallon gas-fired water heater to provide hot water at 150 °F. The existing water heater is an A.O. Smith Master Fit Model BTR 365104 with a rated heat input of 365 MBtu/h. The kitchen's dishwasher has an internal electric heater that boosts water temperature to 185 °F for dish and silver washing. Installation of the Aisin cogeneration unit required the addition of a 120-gallon Amtrol indirect water heater with a double walled heat exchanger. The hot transfer fluid (in this case water) from the Aisin cogeneration unit is circulated through the Amtrol unit by an external 10 gallon per minute (gpm) pump. Cold water supply flows into the Amtrol water heater, where it is preheated to approximately 140 °F. The preheated water is then routed to the existing water heater, where it is further heated to approximately 150 °F.

VERIFICATION DESCRIPTION

Field testing was conducted from July 10 through July 21, 2005. The defined system under test (SUT) was tested to determine performance for the following verification parameters:

- Electrical performance
- Electrical efficiency
- CHP thermal performance
- Atmospheric emissions performance
- Nitrogen oxides (NO_X)and carbon dioxide (CO_2) emission offsets

The verification included a series of controlled test periods on July 20 and 21 in which the GHG Center maintained steady system operations for 3 one-hour test periods to evaluate electrical and CHP efficiency and emissions performance. The controlled tests were preceded by a 10-day period of continuous monitoring to examine heat and power output, power quality, efficiency, and emission reductions. Annual NO_X and CO_2 emissions reductions resulting from the use of the Aisin Seiki system were estimated by comparing measured emission rates with corresponding emission rates for the baseline scenario at Hooligans.

Rationale for the experimental design, determination of verification parameters, detailed testing procedures, test log forms, and QA/QC procedures can be found in the draft ETV Generic Verification Protocol (GVP) for DG/CHP verifications developed by the GHG Center. Site specific information and details regarding instrumentation, procedures, and measurements specific to this verification were detailed in the Test and Quality Assurance Plan titled *Test and Quality Assurance Plan – Aisin Seiki 6.0 kW Natural Gas-Fired Engine Cogeneration Unit.*

VERIFICATION OF PERFORMANCE

Results of the verification are representative of the Aisin Seiki system's performance as installed at Hooligans. Quality Assurance (QA) oversight of the verification testing was provided following specifications in the ETV Quality Management Plan (QMP). The GHG Center's QA manager conducted an audit of data quality on at least 10 percent of the data generated during this verification and a review of this report. Data review and validation was conducted at three levels including the field team leader (for data generated by subcontractors), the project manager, and the QA manager. Through these activities, the QA manager has concluded that the data meet the data quality objectives that are specified in the Test and Quality Assurance Plan.

Also in support of this verification, QA staff from EPA-ORD's Technical Services Branch conducted an on-site technical systems audit (TSA) of the GHG Center's testing activities and procedures. Based on the verification approaches and testing procedures specified in the test plan, the overall conclusion of the audit was that the GHG Center performed well during this verification and there were no significant deviations from the planned activities, measurements, or data quality objectives.

Electrical and Thermal Performance

Table S-2. Aisin Seiki G60 Electrical and Thermal Performance

Test ID	Fuel Input (MBtu/h)	Electrical Power Generation Performance			Heat Recovery Performance		Total CHP System Efficiency (%)
		Power Delivered (kW)	Parasitic Load (kW)	Efficiency [a] (%)	Heat Recovered (MBtu/h)	Thermal Efficiency (%)	
Run 1	76.0	5.32	0.17	23.1	43.3	57.1	80.2
Run 2	75.9	5.30	0.17	23.1	44.6	58.8	81.9
Run 3	76.0	5.31	0.18	23.1	43.0	56.8	79.9
Avg.	**76.0**	**5.31**	**0.17**	**23.1**	**43.6**	**57.5**	**80.6**

[a] Based on actual power available for consumption at the test site (power generated less transformer and circulation pump losses) and the fuel lower heating value (LHV).

- After transformer and parasitic losses, electrical efficiency averaged approximately 23 percent at this site.

- The amount of heat recovered and used for water heating at Hooligans averaged 43.6 MBtu/hr. Corresponding thermal efficiency was 57.5 percent and combined heat and power efficiency averaged 80.6 percent.

- During the 10-day monitoring period, the Aisin unit cycled on and off according to facility hot water demand and operated for a total of total of approximately 61 hours, or 26 percent of the time. During this time, a total of 261.6 kWh electricity was generated and 2,213 MBtu (649 kWh) of heat was recovered and used for water heating. There were no recorded startup failures or periods of unavailability when the unit was commanded to start by hot water demand.

Emissions Performance

Table S-3. Aisin Seiki Emissions During Controlled Test Periods

Run ID	NO_x Emissions		CO Emissions		THC Emissions		CO_2 Emissions	
	ppmv at 15% O_2	lb/MWh	ppmv at 15% O_2	lb/MWh	ppmv at 15% O_2	lb/MWh	%	lb/MWh
Run 1	58	3.1	240	8.1	900	17	7.5	1750
Run 2	61	3.3	250	8.4	920	17	7.5	1720
Run 3	55	3.0	250	8.3	930	18	7.8	1740
Avg.	**58**	**3.2**	**250**	**8.3**	**920**	**17**	**7.7**	**1730**

- NO_X and carbon monoxide (CO) emissions were consistent throughout the testing and averaged 3.1 lb/MWh and 8.3 lb/MWh, respectively. CO_2 emissions averaged 1,730 lb/MWh.

- Concentrations of total hydrocarbons (THC) averaged 2,000 ppm at stack conditions, or 920 ppm at 15% O_2. Results of the methane (CH_4) analyses conducted on composite bag samples averaged 2,340

ppm at stack conditions, or 1,020 ppm at 15% O_2. The THC measurement is considered more reliable since it is an on-site analysis with real time results and all QA/QC criteria were met. The CH_4 results and QA/QC checks indicate that they are suspect and therefore not reported (see Section 2.4.1 of the verification report for details). In any event, it is evident that all or nearly all of the hydrocarbons measured by the THC analyzer are CH_4. THC emission rates averaged 17 lb/MWh.

- Compared to the baseline emissions scenarios for the New York State Independent System Operator (NY ISO) and national grid regions, estimated annual NO_X emissions for the Aisin unit are about 0.003 tons higher than the NY ISO and 0.003 tons (18 %) lower than the national scenario. For CO_2, estimated annual Aisin system emissions are lower than both the NY ISO and national grid regions by 2.2 tons (22 %) and 4.1 tons (34 %), respectively.

Power Quality Performance

- Average electrical frequency was 60.00 Hz and average power factor was 98.0 percent.
- The average current total harmonic distortion (THD) was 2.53 percent and the average voltage THD was 1.76 percent, both well within the IEEE recommended threshold of 5 percent.

Details on the verification test design, measurement test procedures, and Quality Assurance/Quality Control (QA/QC) procedures can be found in the Test Plan titled *Test and Quality Assurance Plan – Aisin Seiki 6.0 kW Natural Gas-Fired Engine Cogeneration Unit* (SRI 2005). Detailed results of the verification are presented in the Final Report titled *Environmental Technology Verification Report for Aisin Seiki 6.0 kW Natural Gas-Fired Engine Cogeneration Unit* (SRI 2005). Both can be downloaded from the GHG Center's web-site (www.sri-rtp.com) or the ETV Program web-site (www.epa.gov/etv).

Signed by Sally Gutierrez (9/30/2005)	**Signed by Tim Hansen (9/30/2005)**
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