UPDATE ON THE STATUS OF THE 250 kW MICROTURBINE DEMONSTRATION PROJECT AT BURBANK LANDFILL

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BACKGROUND

The Burbank Landfill No. 3 has an operating landfill gas extraction system delivering approximately 300 scfm of landfill gas to a small power plant and an adjacent flare station. The landfill gas has methane content between 43 percent and 48 percent. At this site, with financial assistance from the California Energy Commission (CEC) in the form of a Public Interest Energy Research (PIER) Grant, Burbank Water and Power funded the installation of a landfill gas pretreatment and compression skid, and a 250 kW Ingersoll-Rand Energy Systems (IRES) microturbine.

The landfill gas pretreatment and compression skid incorporates moisture knock-out vessels, compressors, a heat exchanger to cool the compressed gas, and a non-regenerable, packed-bed type filter for siloxane removal. The skid utilizes a portion of the landfill gas previously directed to the flare, and supplies ten 30 kW Capstone microturbines and the 250 kW microturbine. The Capstone microturbines were installed in 2001, and sat idle for over three years, until they were able to be reactivated, when the new fuel skid was installed as part of this program.

The 250 kW microturbine was originally intended for natural gas operation. However, with modifications, it became a candidate for landfill gas operation. The CEC-funded project was intended to evaluate the microturbine's ability to operate on landfill gas for one year and to characterize its performance. The one-year demonstration project officially began on June 23, 2005, and this paper contains the material and data gathered after six months of the 12 month demonstration project.

AIR EMISSIONS

Air emissions were measured during the sixth month of operation. The 250 kW microturbine has demonstrated an NO_x emission rate of 0.0237 lb/MMBtu when fired on landfill gas. The microturbine operated at about 0.3 lbs/MWh (gross output) -- an 80 percent reduction in NO_x emissions, as compared to a landfill gas fired reciprocating engine. BACT for a reciprocating engine, when fired on landfill gas, is about 1.8 lbs/MWh (gross output).

The following tables illustrate the microturbine's specified and demonstrated emissions. The 9 ppmv specification was based on natural gas firing, and it was expected that the microturbine would operate at well under 9 ppmv. As a point of reference, IRES 70 kW microturbines and Capstone 30 kW microturbines test out in the range of 1.1 ppmv to 4.2 ppmv at 15 percent O_2; hence, NO_x emissions of the 250 kW microturbine are higher than for the smaller machines.

TABLE NO. 1
NO_X EMISSIONS -- IRES SPECIFICATION AND DEMONSTRATED LEVELS

IRES Specification -- NO_x	Measured Emission -- NOx
< 9 ppmv @ 15% O_2	5.7 ppmv @ 15% O_2
< 0.5 lbm/MWh	0.32 lbs/ MWh

TABLE NO. 2
OTHER PARAMETERS MEASURED DURING SOURCE TEST

Component	Emission Concentration
CO	0.023 lb/hr
NMOC	0.0411 lb/hr as methane
	5.7 ppmv as methane @ 15% O_2
	91.9% destruction efficiency
	7.5 ppmv as hexane at 3% O_2
Particulate	0.0474 lb/hr
SOx	0.0015 lb/hr

GROSS POWER OUTPUT

Utilizing the ambient temperature de-rating curve provided by IRES, as a baseline, the microturbine demonstrated a capacity of 99 percent versus specification. This is illustrated by Figure Nos. 1 and 2. Figure Nos. 1 and 2 plot power output versus ambient temperature. These plots from week four (July) and week twenty-four (December) represent both warm and cool conditions, and demonstrate the similar relationships between power output and ambient temperature in both climates. Combustion turbine power output is directly related to ambient air temperature. Less combustion air mass can be compressed at warmer temperatures since the density of the air is less. Combustion turbine power output is normally rated at 59° F.

The solid line on the plots on Figure Nos. 1 and 2 were provided by IRES and represents the *predicted power* at the given temperature and at an elevation of 1,160 feet (the site elevation). Output was about 99 percent of the predicted output from 50° F to 95° F.

The average power output, during the test run, was 231 kW, and represented 92 percent of nameplate rating. At 1,160 feet elevation and ambient temperatures above 59° F, the *predicted maximum power* of the microturbine is less than 250 kW. The maximum power produced by the unit during the six month period was 259 kW at 49° F, 104 percent of nameplate rating. The predicted maximum power output of the microturbine increases as the temperature drops below 59° F. Overall, the power output did correspond to the *predicted maximum power* curve.

AVAILABILITY

During the six-month demonstration period, the microturbine was available 73.7 percent of the time (i.e., out of service 26.3 percent of the time). Fuel supply issues (wellfield problems or fuel skid problems) caused 10.5 percent of the downtime; thus, the microturbine itself was available 84.2 percent of the time. Microturbine downtime was due to the following:

- Trips due to grid power quality issues = 6.1 percent;
- Downtime due to generator failure (i.e., exciter) = 7.1 percent;
- General maintenance = 0.1 percent; and
- Miscellaneous = 2.5 percent.

The main reason for hours of downtime, other than the generator failure and fuel supply issues, was time spent in recovering from grid power quality trips. Because of limited remote start capabilities, SCS needed support from IRES to start the unit on several occasions. Since the two IRES member local support team was routinely working at other job sites without remote accessibility, and since the one IRES member east coast support team was not available in the afternoons, the unit was routinely down for several hours before it was re-started. If remote start capabilities and coordination are improved, the availability of the microturbine could increase to over 90 percent. Another component that would add to the remote start capability of the microturbine would be to install a remotely activated purge line at the fuel inlet. This would allow for remote restart after a fuel quality failure.

HEAT RATE

The microturbine operated with an average heat rate of 12,417 Btu/kWh during the six-month performance test. The monthly average values are listed on Table No. 3.

TABLE NO. 3
MONTHLY AVERAGE HEAT RATES

Month	Heat Rate (Btu/kWh)
June	12,666
July	12,665
August	12,444
September	12,468
October	12,211
November	12,053

The apparent improvement in heat rate over time prompted additional investigation. The investigation is summarized in Figure Nos. 3 and 4.

The heat rate of the microturbine for the fourth week (July) and the twenty-fourth week (December) is shown as a function of ambient temperature on Figure Nos. 3 and 4. Figure No. 5 is a combined plot of the plots from Figure Nos. 3 and 4.

Figure No. 5 indicates that the heat rate at 59° F, and 1,160 feet elevation, averaged 11,800 Btu/kWh. It did not appear as if there was deterioration in heat rate over time. Heat rate will be watched carefully during the second half of the test program. IRES's specified heat rate for this machine was 19,900 Btu/kWh at ISO conditions of 59° F and 0 feet elevation; thus, the machine met expectations.

Heat rate varied as a function of ambient air temperature, increasing from about 12,000 Btu/kWh at 59° F to about 13,900 Btu/kWh at 100° F. Heat rate increased by about 16 percent over this temperature range. Deterioration in heat rate with an increase in temperature is expected, since the microturbine needs to do more work to compress the same mass of less dense air at higher air temperatures. IRES did not provide heat rate correction factors for elevation and temperature.

OTHER LANDFILL GAS CHARACTERISTICS

Siloxane values obtained from the feed stream for the first six months are shown on Table No. 4.

TABLE NO. 4
SILOXANE CONCENTRATIONS

Month	Siloxane concentration	Comments
June	3.14×10^{-3} lbs/mmBtu	Raw landfill gas
July	0.657×10^{-3} lbs/mmBtu	Raw landfill gas
August	0 lbs/mmBtu	Post pretreatment
September	0 lbs/mmBtu	Post pretreatment
October	0.58×10^{-3} lbs/mmBtu	Saturated pretreatment system
November	0.727×10^{-3} lbs/mmBtu	Saturated pretreatment system

SCS Energy and IRES had several discussions about whether or not to pretreat the landfill gas for siloxane. SCS Energy felt that to not pretreat would provide an opportunity to evaluate the resilience of the 250 kW microturbine. IRES was concerned that siloxane induced problems would complicate what might otherwise be a successful demonstration of the 250 kW microturbine. In somewhat of an unintended compromise, the 250 kW microturbine did see some siloxane. Activated carbon was used to remove siloxane beginning on August 28, 2005. The activated carbon reached saturation in October 2005. The activated carbon was replaced with silica gel on January 24, 2006.

Hydrogen sulfide values obtained from the feed stream for the first six months are shown on Table No. 5.

TABLE NO. 5
HYDROGEN SULFIDE CONCENTRATIONS

Month	Hydrogen Sulfide concentrations	Comments
June	18.8 ppmv	Raw landfill gas
July	20.2 ppmv	Raw landfill gas
August	<0.5 ppmv	Post pretreatment
September	<0.5 ppmv	Post pretreatment
October	<0.5 ppmv	Saturated pretreatment system
November	<0.5 ppmv	Saturated pretreatment system

Non-methane Organic Compound (NMOC) concentrations obtained from the feed stream are shown on Table No. 6.

TABLE NO. 6
NMOC CONCENTRATIONS

Month	NMOC as Methane	Comments
June	2060 ppmv	Raw landfill gas
July	1900 ppmv	Raw landfill gas
August	348 ppmv	Post pretreatment
September	624 ppmv	Post pretreatment
October	1640 ppmv	Saturated pretreatment system
November	3080 ppmv	Saturated pretreatment system

FUEL GAS METHANE PERCENTAGE

The microturbine has been fueled with landfill gas whose methane concentration has had characteristics shown on Table No. 7. During the second six months of the test program, lower methane concentrations will be induced to test the limits of the 250 kW microturbine.

TABLE NO. 7
FUEL GAS METHANE CONCENTRATIONS

Average methane concentration	46% methane
Range of methane concentration	39.7% to 50.9% methane
Demonstrated successful operation down to	39.7% methane

ECONOMIC CONSIDERATIONS

The total installed 250 kW microturbine unit cost was $2,115/kW. That price included the microturbine, adjusted pretreatment skid costs, carbon filters for siloxane removal, adjusted instrumentation cost and adjusted installation labor cost. The reason for the adjustments was to compensate for the oversizing of the pretreatment skid. The skid and its installation were designed to accommodate both the 250 kW microturbine and ten 30 kW Capstone microturbines. For this reason, the cost of the skid, instrumentation and installation labor were adjusted to 75 percent of the actual cost.

The operation/maintenance cost was \$0.05/kWh, also on an adjusted basis. This was based on service costs of IRES at \$1,900 per month, an adjusted SCS service cost of \$3,000 per month for the site operations, and an annualized cost of siloxane removal media replacement of \$16,000. The above costs were divided by the amount of energy generated during the six month period (733,137 kWh).

The reason for the adjusted service cost was to make the value more representative of an operational site with only a 250 kW microturbine. The non-adjusted cost per month for site operations is \$7,500 per month. The non-adjusted cost accounts for a larger site (550 kW versus 250 kW) and more extensive operations to accommodate research and ground breaking operations. If availability increases as expected, the operation/maintenance cost will drop to the vicinity of \$0.04/kWh.

OTHER

A borescope exam was performed on September 12, 2005. There was not anything found that IRES expressed concern over. Small deposits were detected in the inner-workings of the microturbine in amounts not expected to cause any damage to the machine. Also with the introduction of siloxane removal technology, siloxane is not expected to cause any problems.

CONCLUSIONS

The Burbank 250 kW microturbine demonstration project has shown that the IRES 250 kW microturbine can operate successfully on landfill gas at methane concentrations as low as 39 percent. The 250 kW microturbine has generally met expectations for power output, heat rate and air emissions. Availability was somewhat less than desired during the first six months of operation, but an availability of 90 percent appears to be attainable.

FIGURE NO. 1
MICROTURBINE POWER OUTPUT VERSUS AMBIENT TEMPERATURE
FOR WEEK FOUR

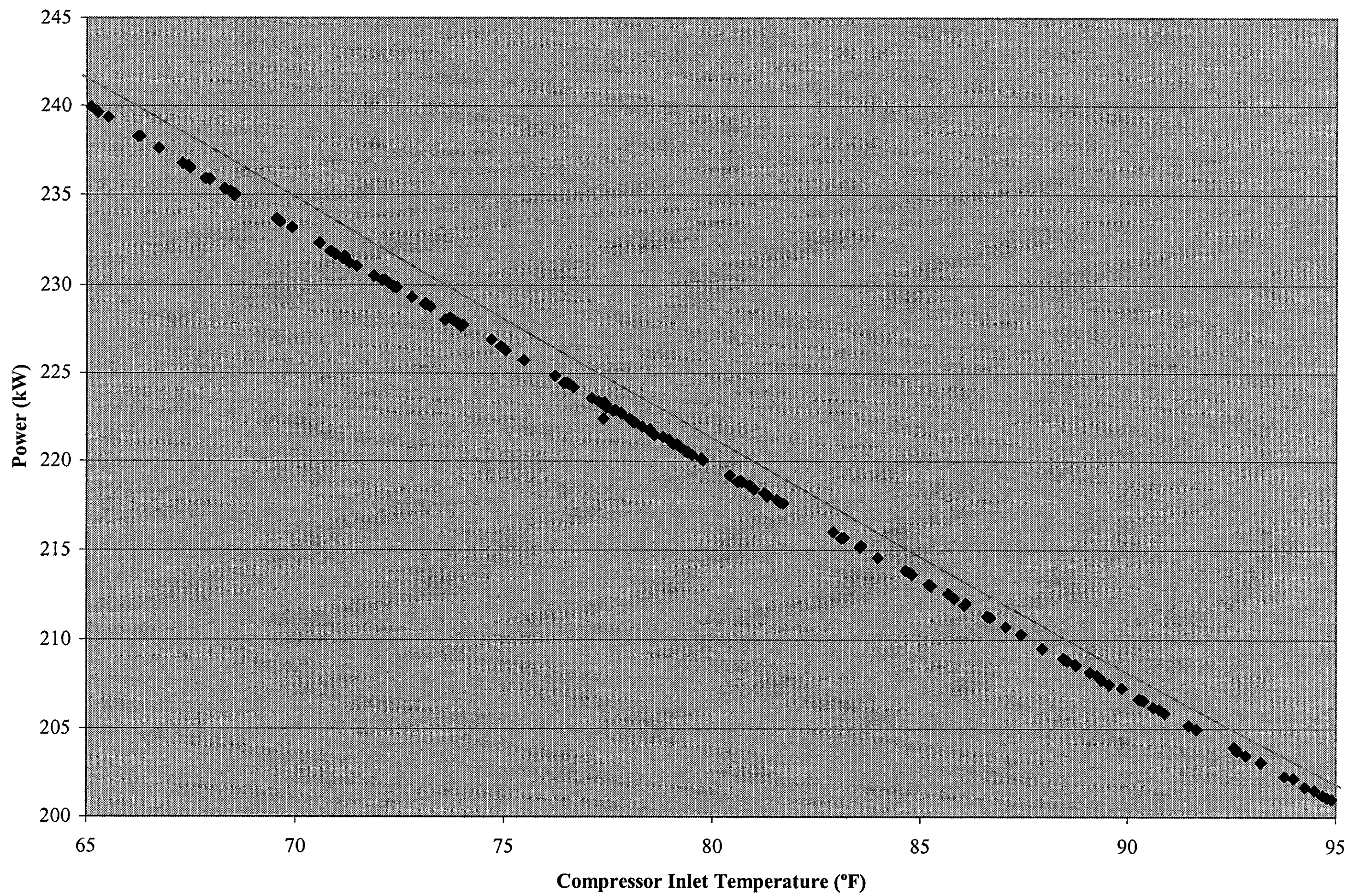

FIGURE NO. 2
MICROTURBINE POWER OUTPUT VERSUS AMBIENT TEMPERATURE
FOR WEEK TWENTY-FOUR

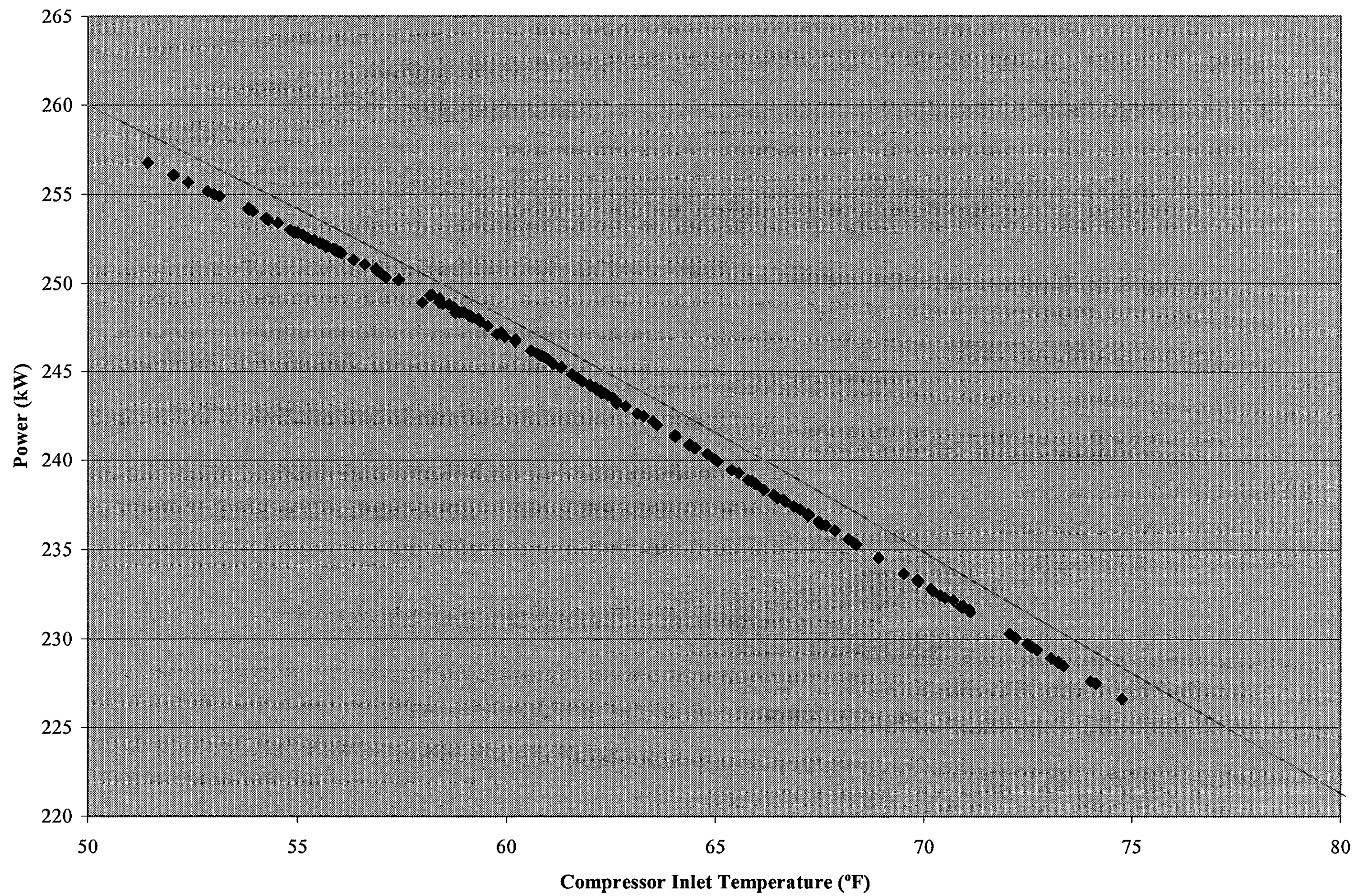

FIGURE NO. 3
MICROTURBINE HEAT RATE
AS A FUNCTION OF AMBIENT TEMPERATURE FOR WEEK FOUR

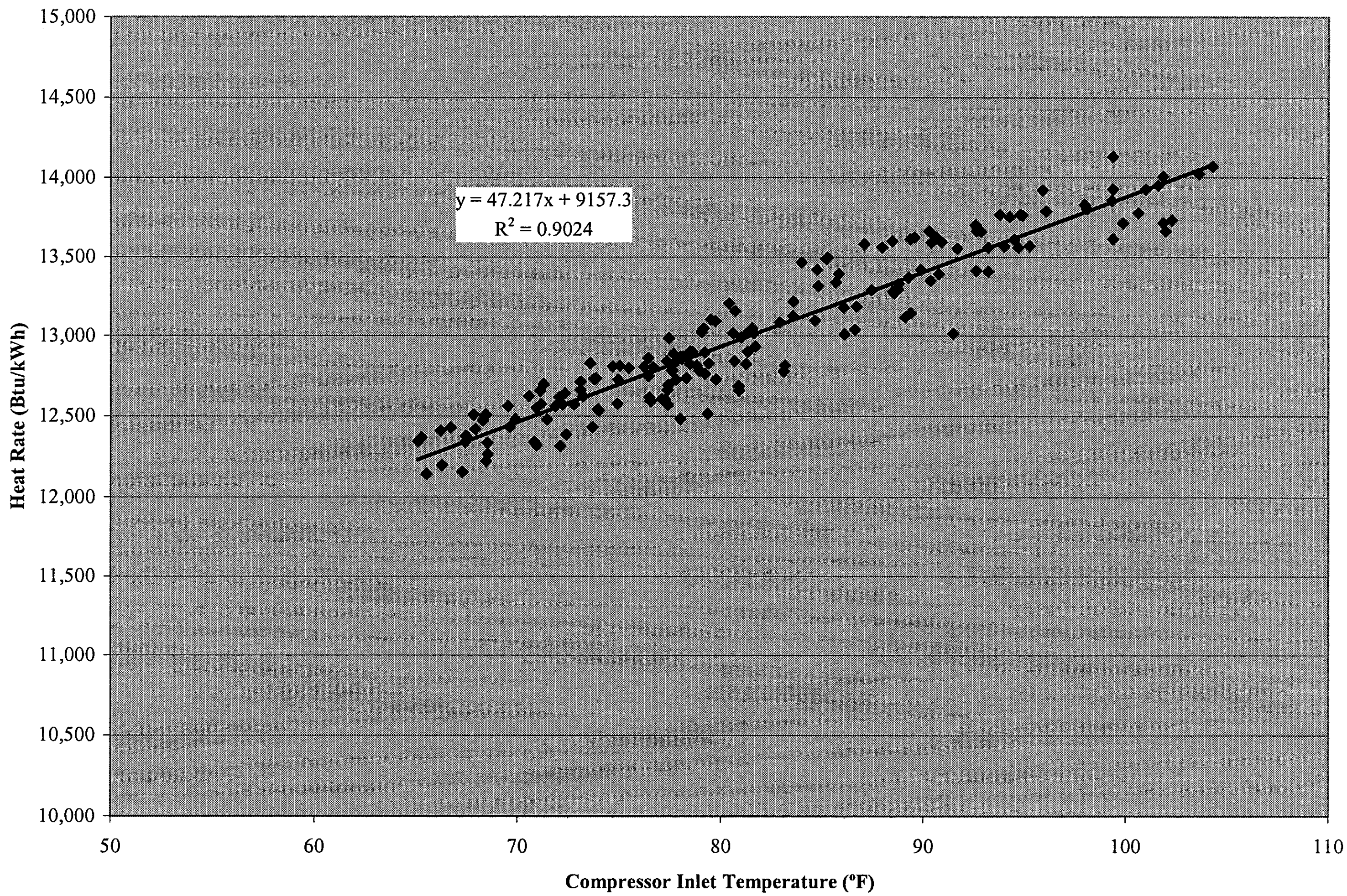

FIGURE NO. 4
MICROTURBINE HEAT RATE
AS A FUNCTION OF AMBIENT TEMPERATURE FOR WEEK TWENTY-FOUR

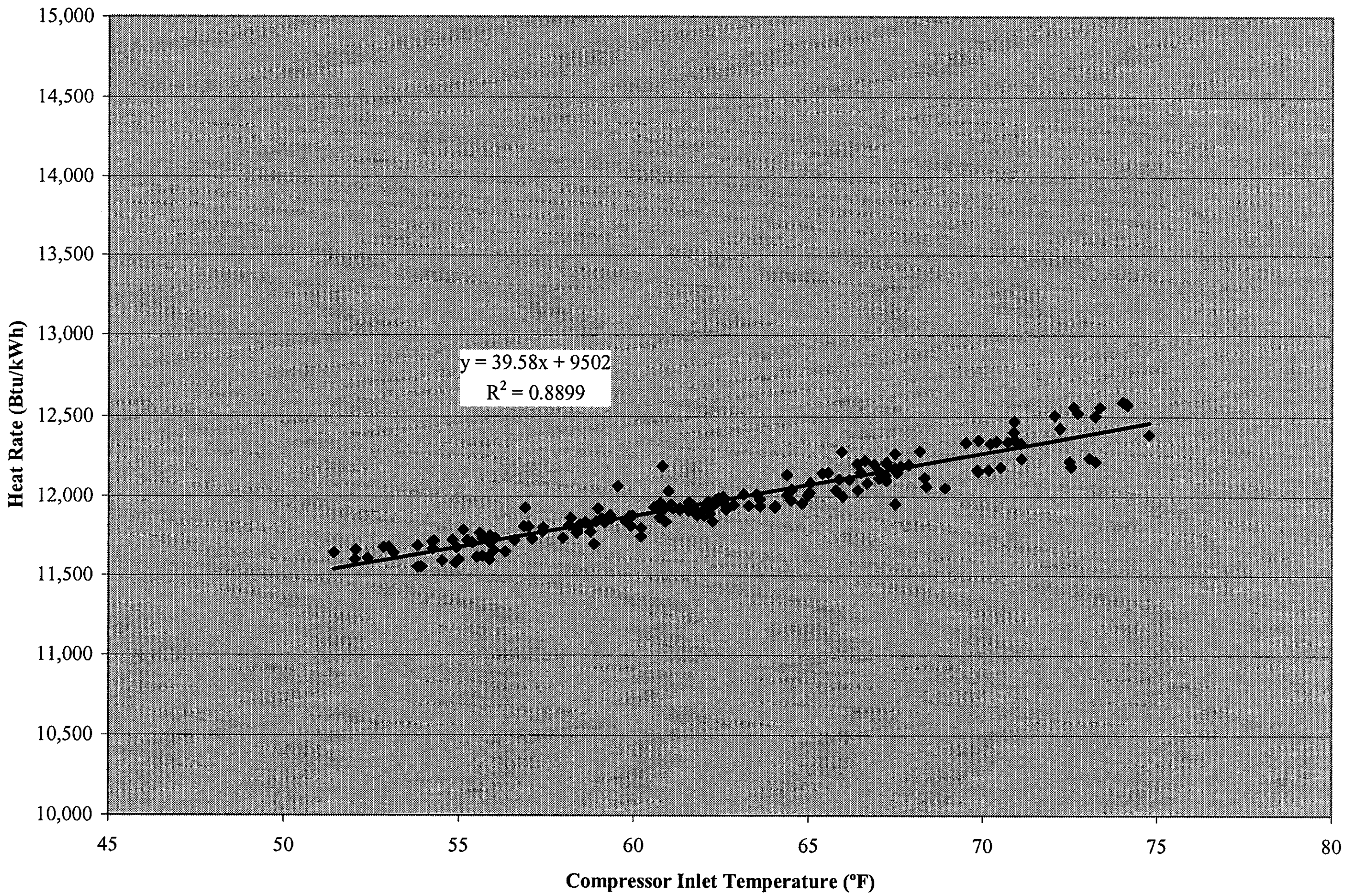

FIGURE NO. 5
MICROTURBINE HEAT RATE AS A FUNCTION OF COMPRESSOR INLET TEMPERATURE
FOR WEEKS FOUR AND TWENTY-FOUR