SCE/DOE

Microturbine Generator Testing Program

SCE Testing Program

Goal:

- Determine the performance, reliability, operability, operational availability, maintainability, and overall characteristics of commercially available MTGs

Objective:

- Compare MTGs' actual performance to manufacturer's specifications and other standards, such as emissions

Accomplishments:

- $4.0+ million program since 1996
- 16 different MTGs tested or in testing; more expected
- “Live” browser technology
- Machine Performance test
- Electrical behavior testing

- **Over 80,000 hours of testing**

SCE TEST BED AT UCI

- 4 test bays
- 480 amp,480 volts service
- 100 psig natural gas- ability to blend for lower Btu testing
- Cogeneration heat dissipation
- Canopy to protect MTGs from weather
- Instrumentation for gas and electronic data acquisition
- Standardized testing procedure
- Ability to perform specialized /custom testing
- Veteran two-person on-site testing crew

Operational Summary

MTG	Installation Date	Total-Op. Hours	Status
Capstone "B" 30 kW	Jan-97	958	Completed
Capstone "B" 30 kW	Jan-97	967	Completed
Capstone 10 Pack	Apr-97	26	Completed
Capstone "C" 30 kW	May-97	3,794	Completed
Capstone "C" 30 kW	Jul-97	2,079	Completed
Bowman 35 kW	Feb-99	100	Completed
Bowman 60 kW	Jun-99	60	Completed
Honeywell Parallon 75 kW	Jun-00	5,806	Completed
Capstone HP 30 kW	Apr-99	21,984	Completed
Capstone LP 30 kW	Aug-00	16,085	Completed
Bowman 80 kW	Jun-01	15,962	Completed
Elliott 80 kW	Jan-02	2,932	Replaced
Ingersoll-Rand 70 kW	Nov-02	6,014	Completed
Elliott 100 kW	Jun-04	5,871	Completed
Ingersoll-Rand 250 kW	Nov-05	0	Ongoing
Total		**82,648**	

MTG Data Acquisition

- 4 MTG skids available, but only 3 units may be monitored at a time (due to limitations of electrical distribution panel)
- One phone line and phone line sharing device used to optimize data collection
- Campbell Scientific CR10X datalogger used to collected 5 minutes intervals data
- BMI PQ node used to capture events and PQ snapshots
- Data consist of
  - Intervals data sets: environmental, gas, electrical
  - Calculated data: efficiency, capacity factor, availability, fuel rate and heat rate.

Desirable Attributes vs. Test Parameters

- ATTRIBUTES
  - Heat rate 12,000 to 16,000 BTU/kWh
  - Good Part Load Performance
  - Emissions < 9 ppm
  - Power Quality < IEEE 519
  - Noise < 70 dBa
  - Endurance = 40,000 hours
  - Installation = Easy & Cheap

- TEST PARAMETERS
  - Overall unit efficiency
  - Net Power Output
  - Emissions
  - Power Quality
  - Noise
  - Endurance
  - Ease of Installation
  - Operability
  - Maintainability

Data
Capture & Calculated

Data Capture

- AC power/Current
- Flow
  - Gas and Water
- Pressure
  - Barometric
  - Gas
- Temperature
  - Ambient
  - Water (inlet & outlet)
  - Natural Gas
- Ambient relative humidity

Calculated Data

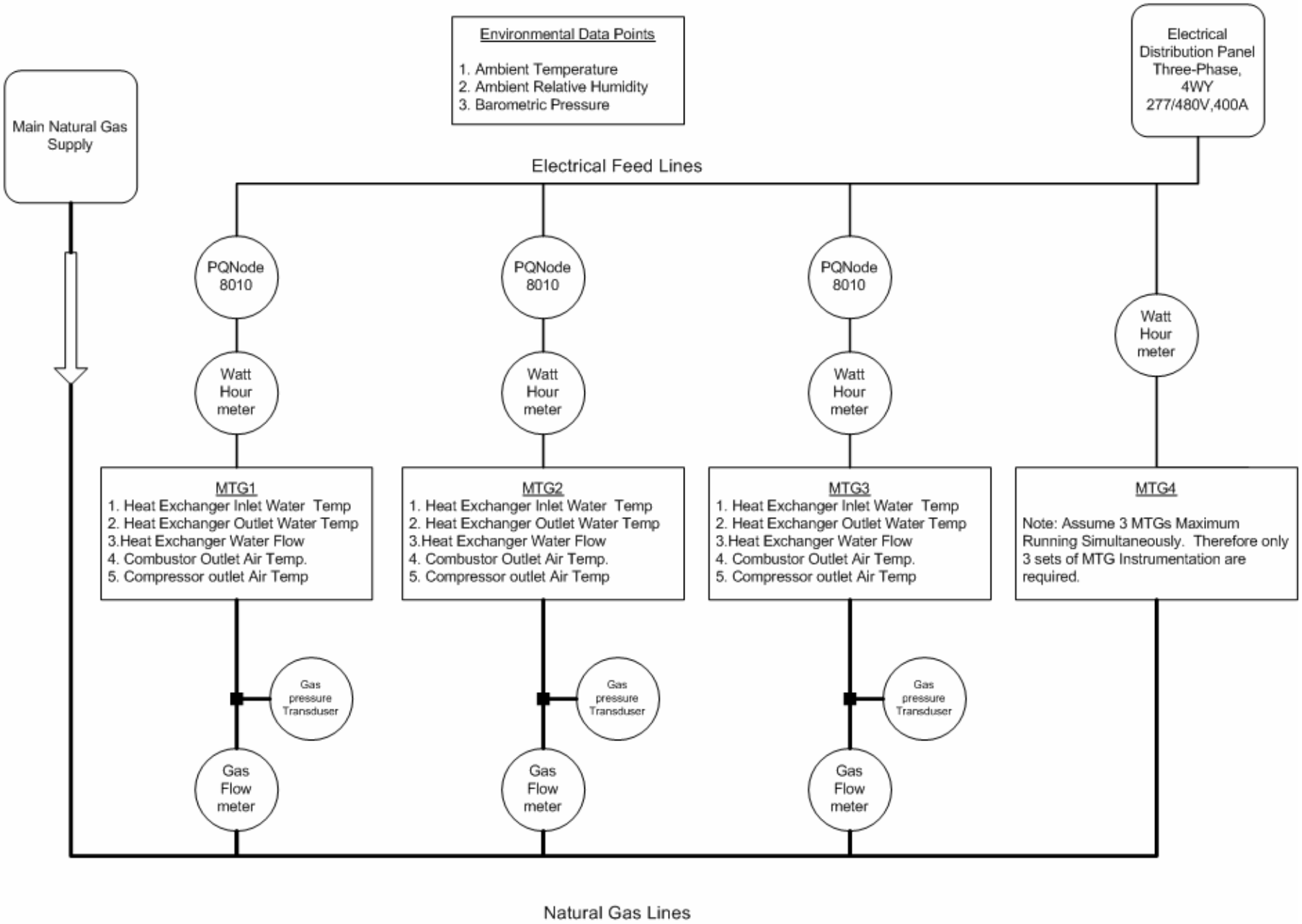
- Heat rate
- Operating Hours
- MTG system efficiency
- Total Harmonics Distortion
- Power Quality

Data Acquisition System

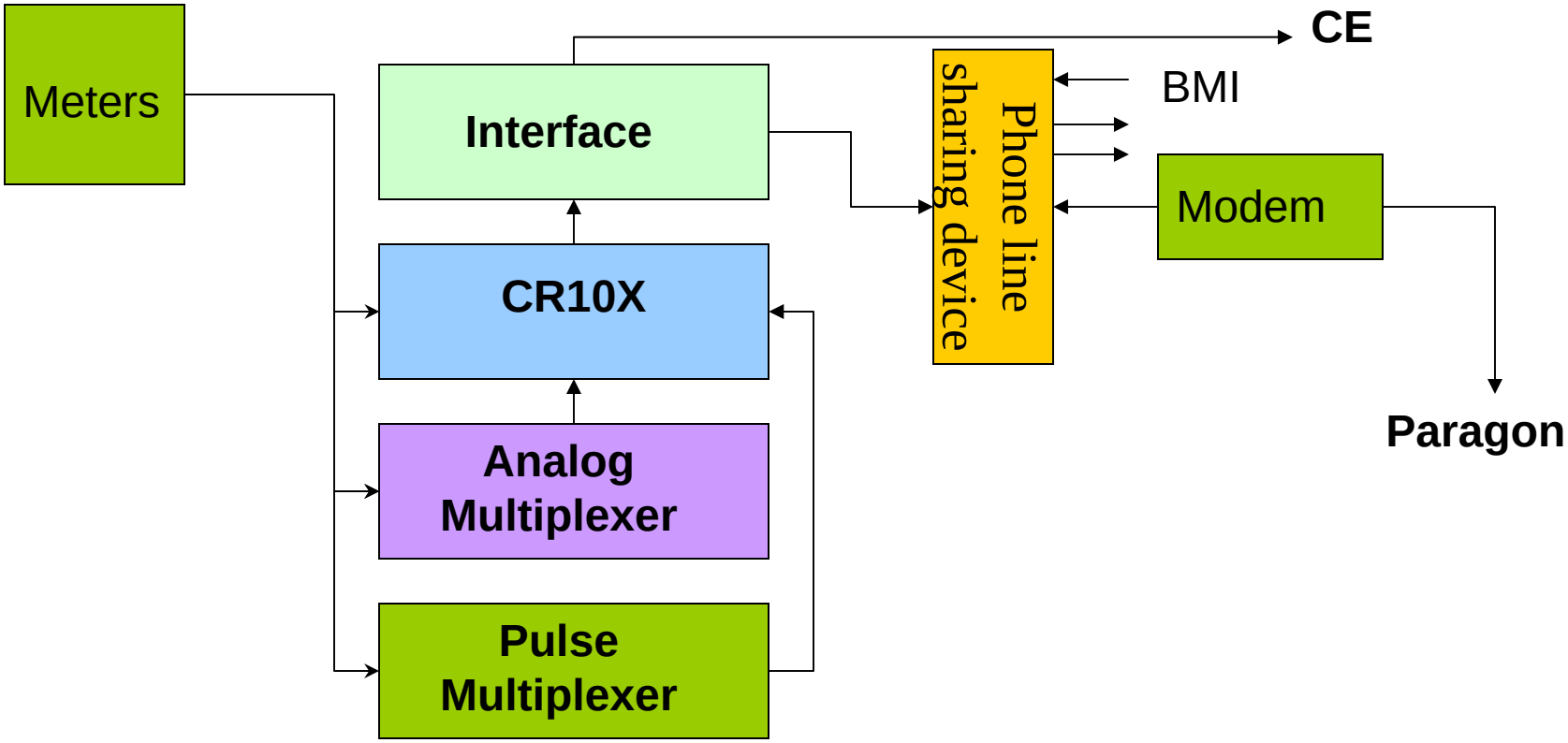
Parameter	Measuring Instrument
Electrical Energy Produced	3-phase electrical meter with pulse output module
Fuel Consumed (Gas Flow)	Gas flow meter
Fuel Temperature	Resistance Thermal Detector (RTD)
Gas Pressure	Pressure transducer
Water Flow	Water flow meter
Boiler Air Temperature – Inlet and Outlet	Thermocouple
Water Temperature – Inlet and Outlet	RTD
Power Quality Snapshots	BMI 7100 and BMI 8010 power quality meters
Ambient Temperature	Temperature Probe
Relative Humidity	Solid State IC
Barometric Pressure	Barometric pressure transducer

MTG Instrumentation Layout

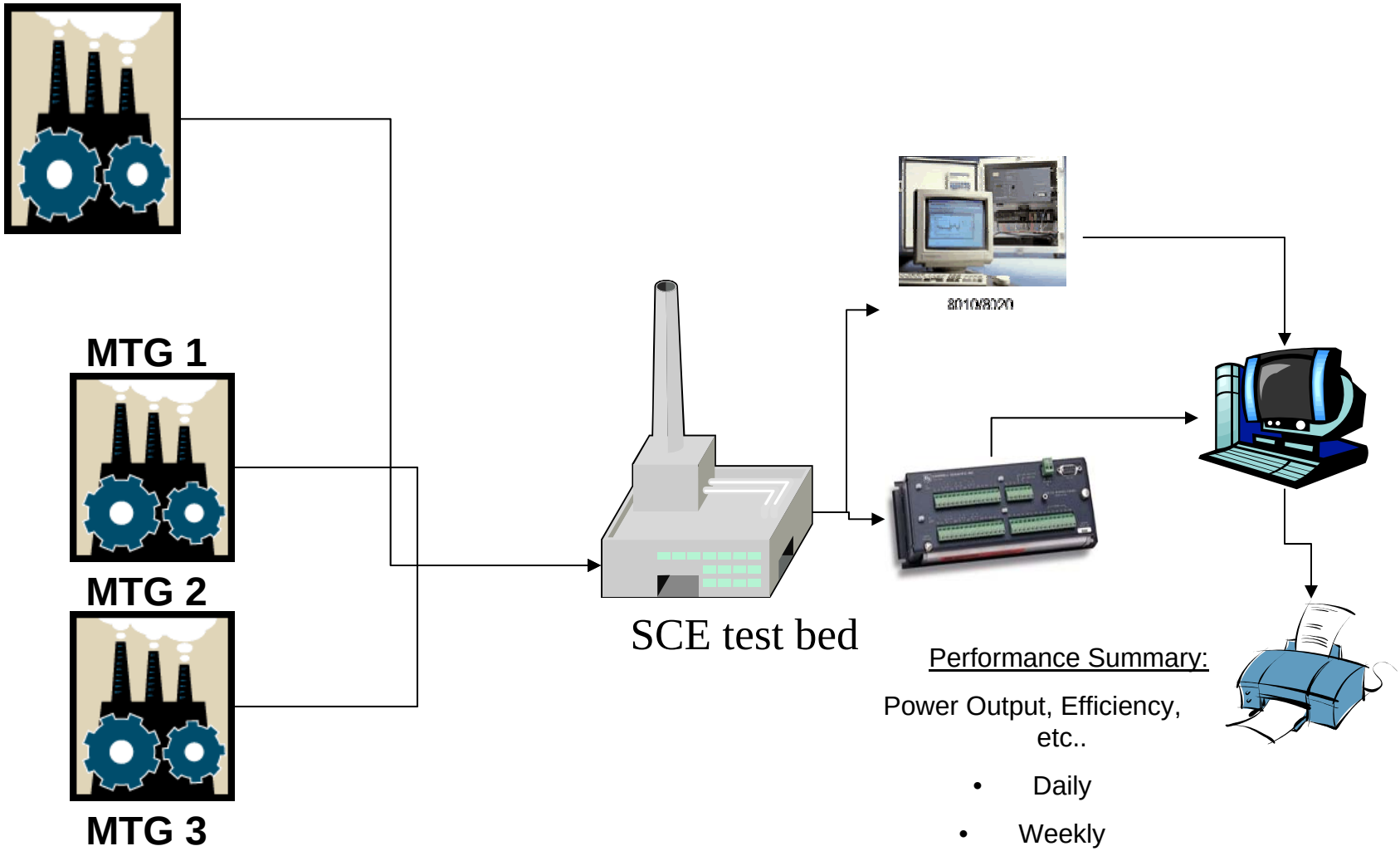
Southern California Edison



Data Acquisition System



Instrumentation Data Flow



Performance Summary:

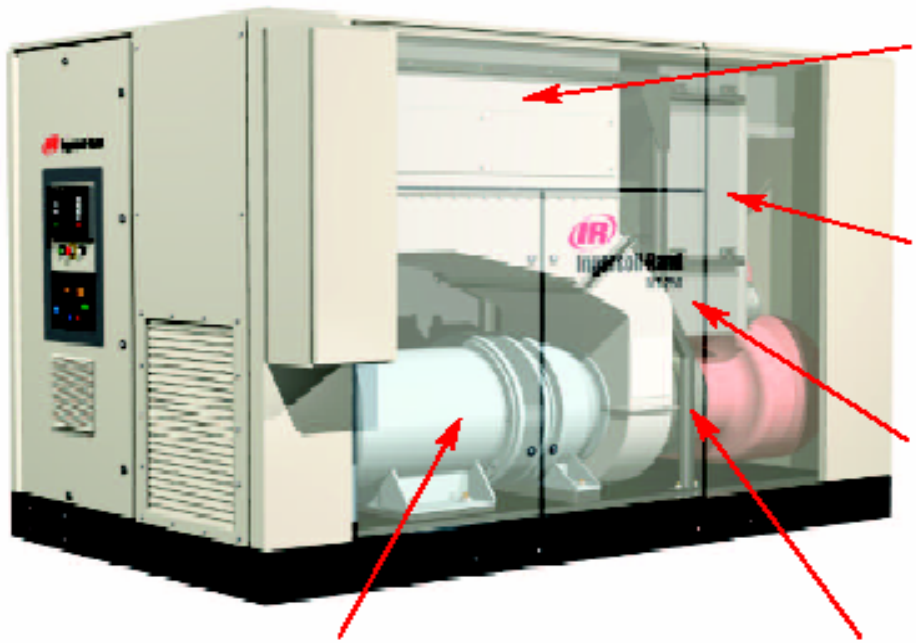
Power Output, Efficiency, etc..

- Daily
- Weekly
- Monthly

Testing Program Future

- Newer and larger microturbines
  - Implement Field and Long Term ASERTTI Test Protocols
  - Capstone 200 kW
  - Other Future MTGs
- Other DG technologies
  - Stirling Engines
  - Photovoltaic Panels
  - Fuel Cells

Ingersoll Rand 250 kW Microturbine



Integrated Heat Recovery
- Controllable output level
- Reduces overall footprint
- No ducting

Patented Recuperator
- Critical to high efficiency
- Design life of 80,000 hours

Patented Combustor
- Dry low NOx
- Easily meets stringent environmental regulations

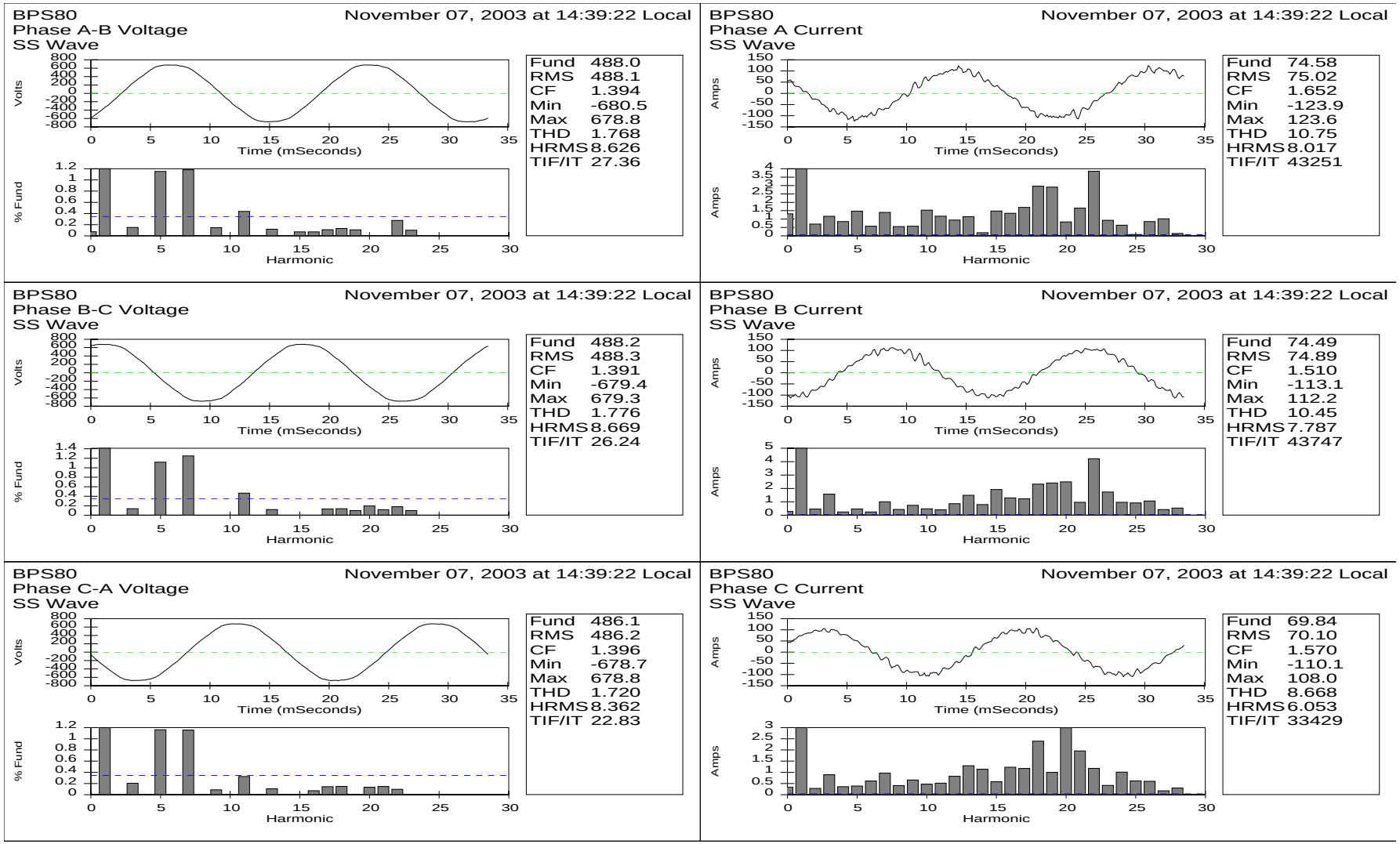
Synchronous Generator
- Same technology used by utilities to power the grid
- Provides running backup capability

Rugged Turbine Engine
- Based on KG2 engine design
- Back-to-back rotating components
- All bearings at cold end

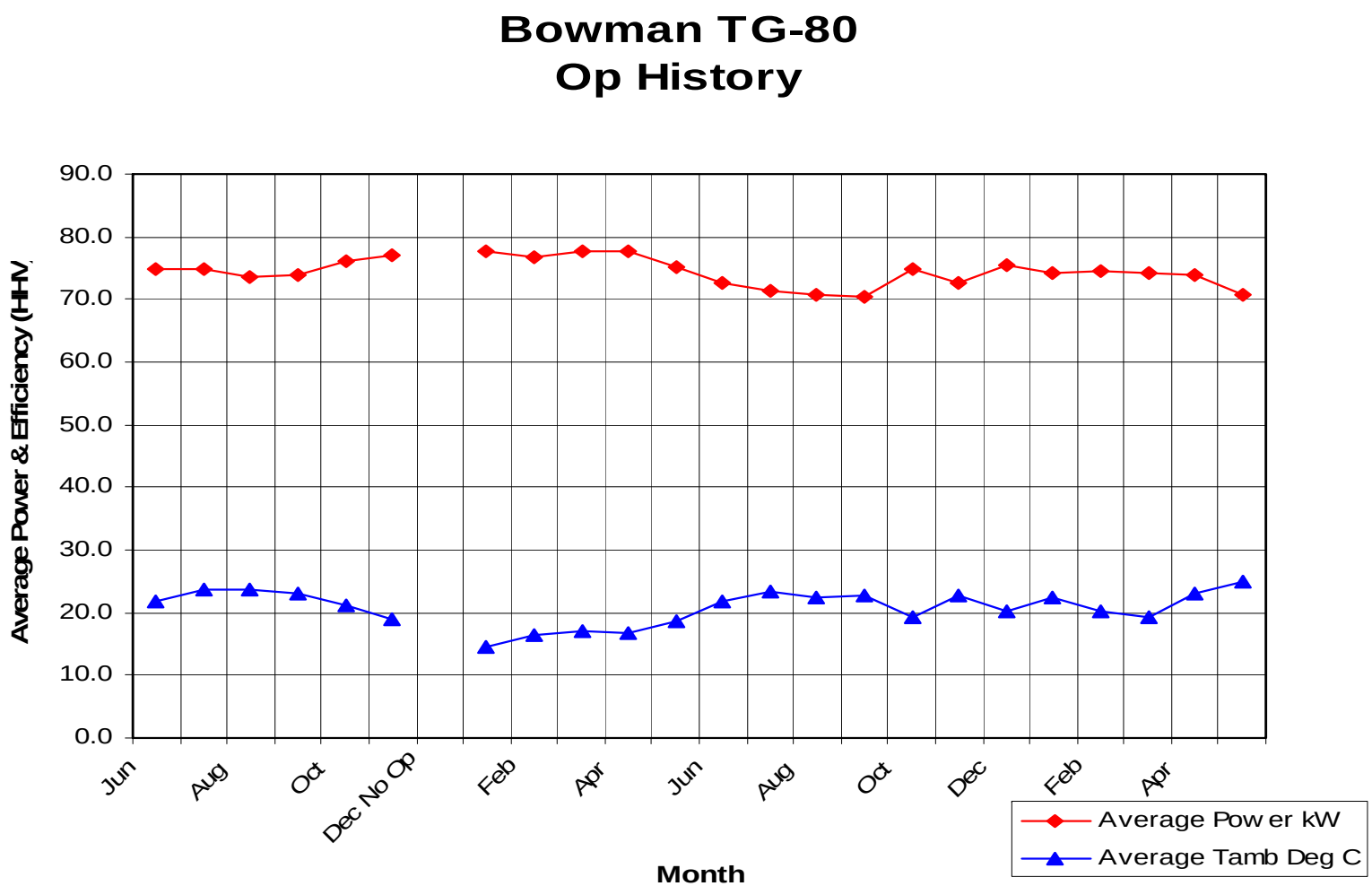
Bowman 80 kW CHP Description

- Bowman 80 kW at ISO
- 480 VAC, 3-phase, 60 Hz
- Recuperated single stage radial flow compressor and turbine on a single shaft, integrated with generator
- Integrated heat recovery boiler
- In grid parallel operation
- Will test stand-alone operation

Bowman 80 Power Quality Profile



Power Output Dependence on Ambient Temperature



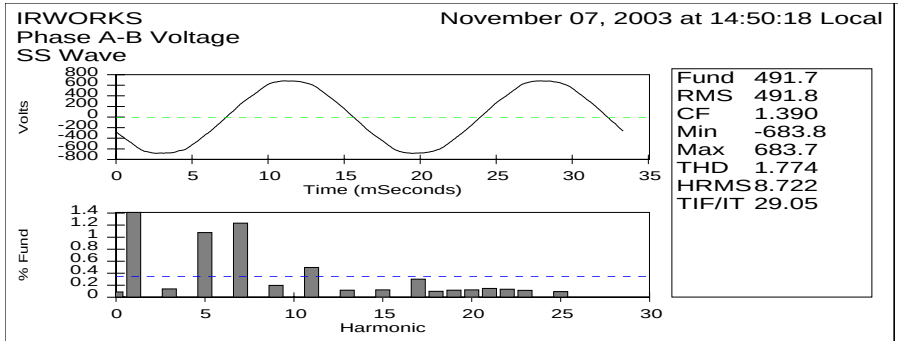
Summary of Testing Results

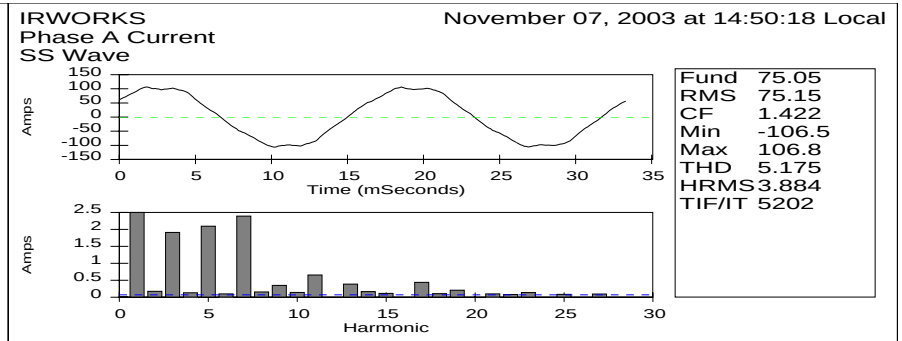
- 1997
  - Testing of Capstone units (Beta, Charlie – pre-commercial)
  - Did not meet manufacturer's expectations
  - First & second generation units
  - Began testing "next generation" in 1999
- 1998
  - No MTGs commercially available to purchase and test
- 1999 Testing of Bowman units (pre-commercial)
  - Did not meet manufacturer's expectations
  - First generation units;
  - Began testing "next generation" in 2001
- 1999 Testing of High Pressure Capstone unit
  - Met manufacturer's claims
  - Fourth generation unit
  - Began testing "next generation" in 2000
- 2000
  - Capstone high pressure unit's DPC upgraded and replaced resulting in higher power output and increased efficiency
  - Began testing low pressure Capstone and Honeywell

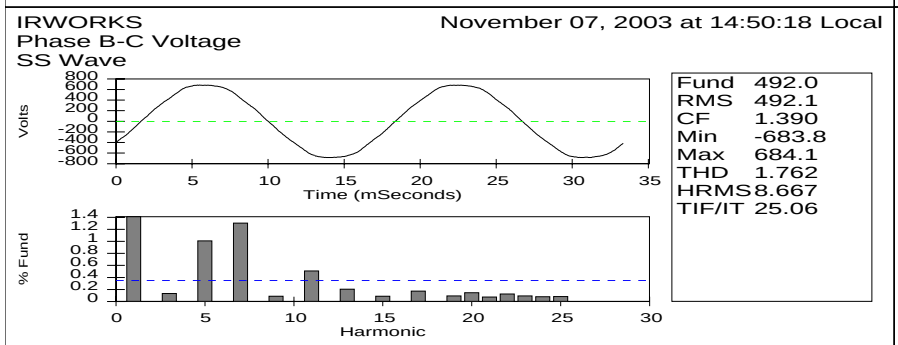
Summary of Testing Results

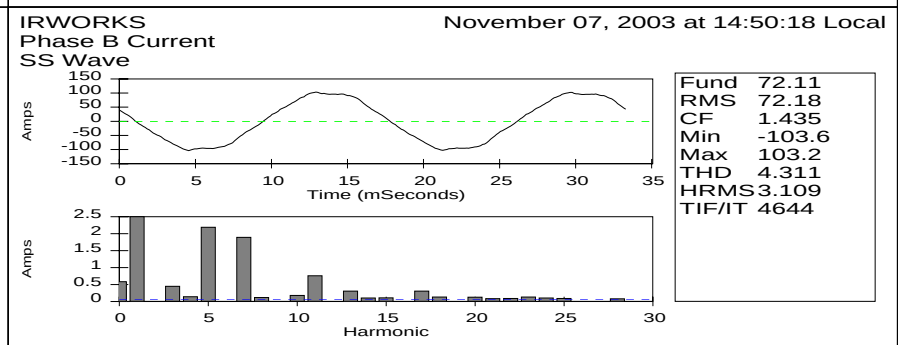
- 2001
  - Initial results for Capstone both LP and upgraded HP
  - Honeywell results
  - Began testing Bowman
  - Elliott returned to manufacturer for upgrade
  - Elliott returned to UCI test site and testing to resume
- 2002
  - Begin testing of Ingersoll-Rand
  - Seek other MTGS, such as Capstone 60 kW, Turbec 100 kW CHP
  - Finalize results for Capstones and Bowman
- 2003
  - Elliott 80kW testing replaced at UCI with Elliott 100kW
  - Ingersoll Rand 70kW testing completed at UCI
- 2004
  - Bowman 80 KW machine installed at Hydro Quebec for additional testing
  - Elliott 100kW testing completed at UCI
- 2005
  - Bowman 80 kW MTG testing continues at Hydro Quebec
  - Ingersoll-Rand 250 kW machine installed at UCI

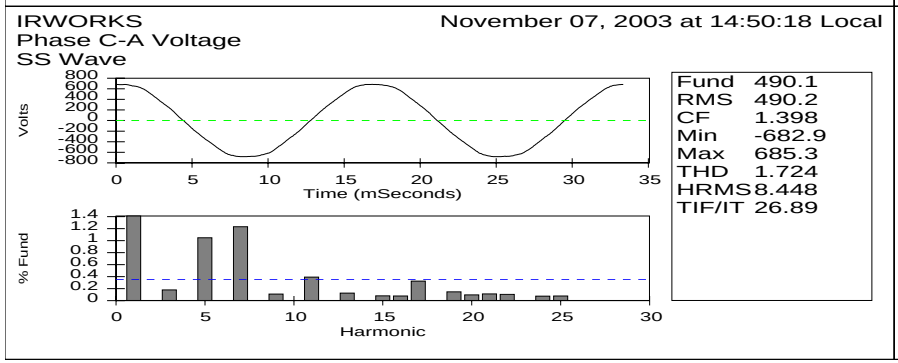
Ingersoll Rand 70S Power Quality Profile

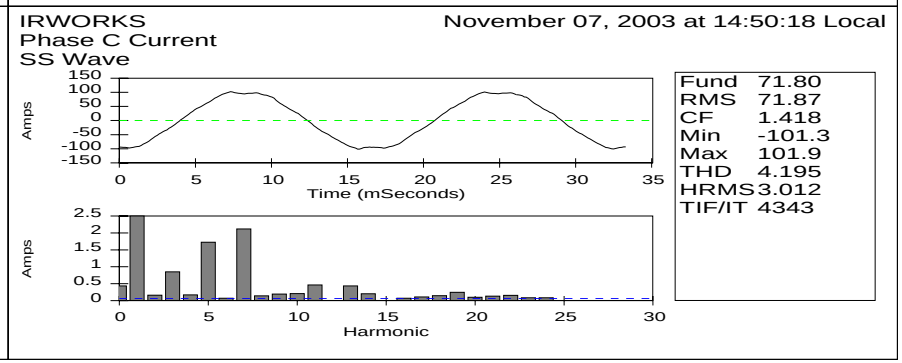












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Welcome: Stephanie Hamilton

Powered By: Connected Energy Corp.

Efficiency	23.1 %	0.00 %
Efficiency (CHP)	23.1 %	%
Electric Output	57.8 kW	0.0 kW
% of Rated Output	94.0 %	0 %
Heat Output	0.00 TPH	0.25 TPH
STATE		Idle

IR Data Updated	13:02 on 11/19/2003
Bow. Data Updated	13:02 on 11/19/2003
Other Data Updated	13:02 on 11/19/2003

Ambient Temp.	95.5 Deg F
Rel. Humidity	12.9 %
Bar. Pressure	14.7 PSIA
Date	11/19/2003
Local Time	13:03

IR PowerWorks

Bowman TC-80-CG

Stephanie.Hamilton@sce.com

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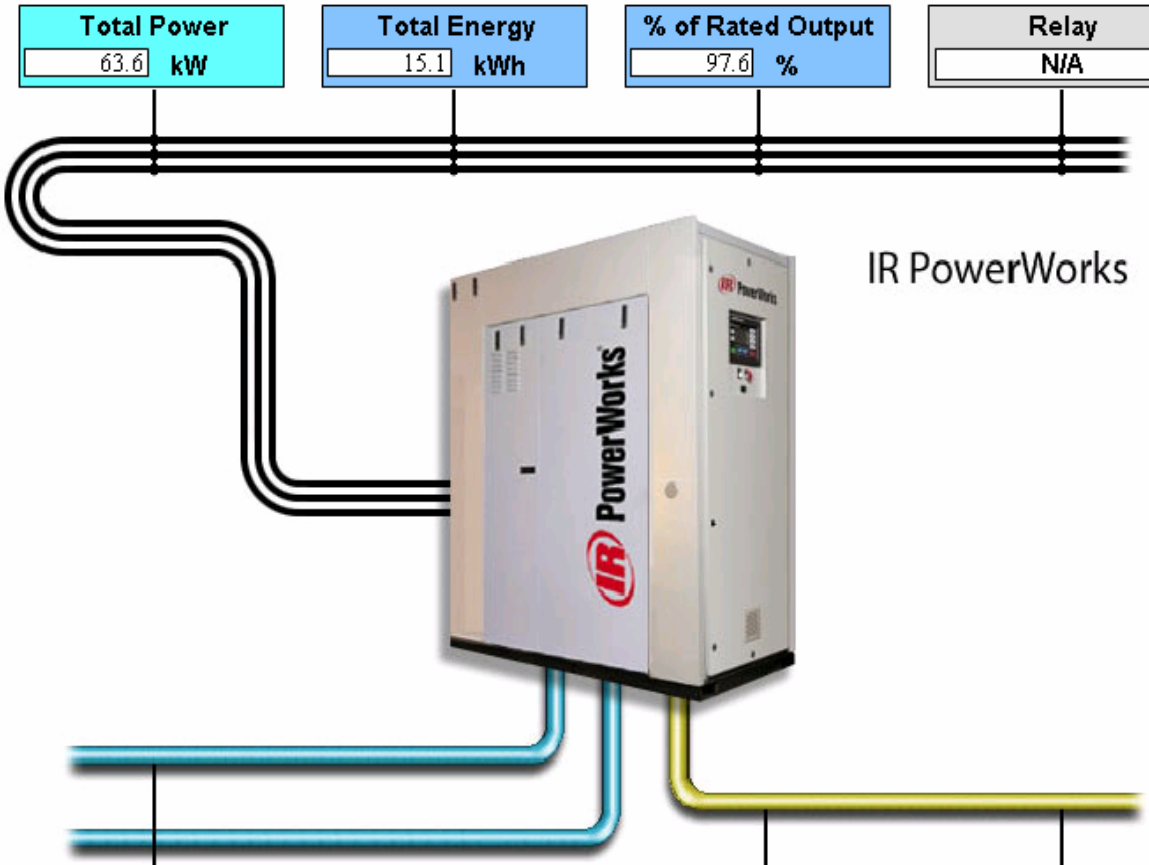
Total Power	Total Energy	% of Rated Output	Relay
63.6 kW	15.1 kWh	97.6 %	N/A

Runtime
3870.3 Hours

# of Starts
121



Date
11/20/2003
Time
12:31

Heat Output	Inlet Temperature	Fuel Pressure	Fuel Flow
0.00 TPH	93.2 Deg F	16.7 PSIG	15.3 SCFM
Water Flow	**Outlet Temperature**		**Fuel Temperature**
0.0 GPM	116.4 Deg F		78.4 Deg F

IR Data Updated
12:31 on 11/20/2003
Other Data Updated
12:31 on 11/20/2003

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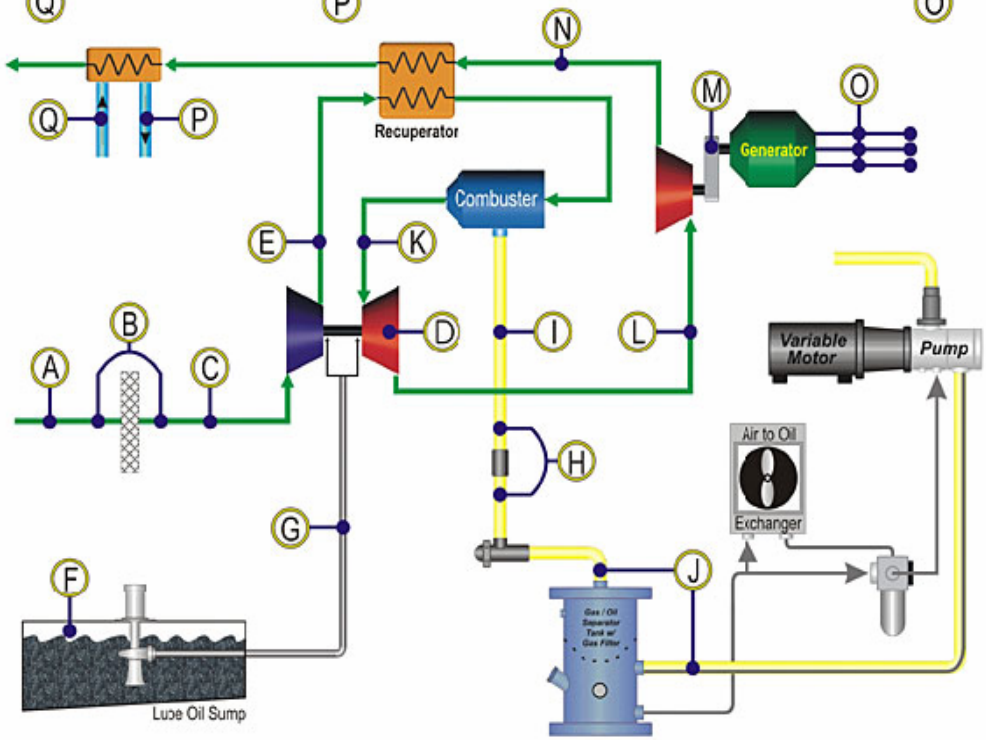
Vibration	0.07 IPS
Water Inlet (Q)	110.3 Deg F
Water Outlet (P)	162.2 Deg F
KW Set Point (O)	92.0 KW
Run Time	3846.5 Hours
No. Of Starts	121
Ambient Pressure (A)	14.7 PSIG
Inlet Filter DP (B)	2.0 IWC
Compressor Inlet (C)	82.2 Deg F
Engine Speed (D)	71200.7 RPM
Discharge Temp. (E)	358.7 Deg F
Discharge Pressure	49.9 PSIG
Recuperator Inlet (N)	Deg F
Generator Speed (M)	3600.5 RPM
Gasifier Discharge (L)	1296.5 Deg F
Gasifier Inlet (K)	1544.1 Deg F
Gasifier Outlet	1303.6 Deg F
	1303.6 Deg F
	1263.6 Deg F
Fuel/Oil Separator (J)	0.0 PSIA
Lube Oil Tank (F)	0.7 PSIG
Oil Pressure (G)	55.2 PSIA
Fuel Flow DP (H)	PSID
Fuel Discharge (I)	52.0 PSIA
Software Number	0
IR Data Updated	13:14 on 11/19/2003



Gas Feed
Gas/Oil Mix
Oil Return
Lube Oil Feed
Air Path

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Total Power	Total Energy	% of Rated Output	Reactive Power
0.0 kW	902429.9 kWh	0 %	N/A kVAR

Runtime
15093 Hours

# of Starts
127

Ambient Temp.
94.7 Deg. F

Date
11/19/2003

Time
13:14

Heat Output	Outlet Temperature	Fuel Pressure	Fuel Flow
0.00 TPH	108.8 Deg. F	93.9 PSIG	0.0 SCFM
Water Flow	**Inlet Temperature**		**Fuel Temperature**
33.0 GPM	108.8 Deg. F		88.2 Deg F

Bow. Data Updated
13:13 on 11/19/2003

Other Data Updated
13:12 on 11/19/2003

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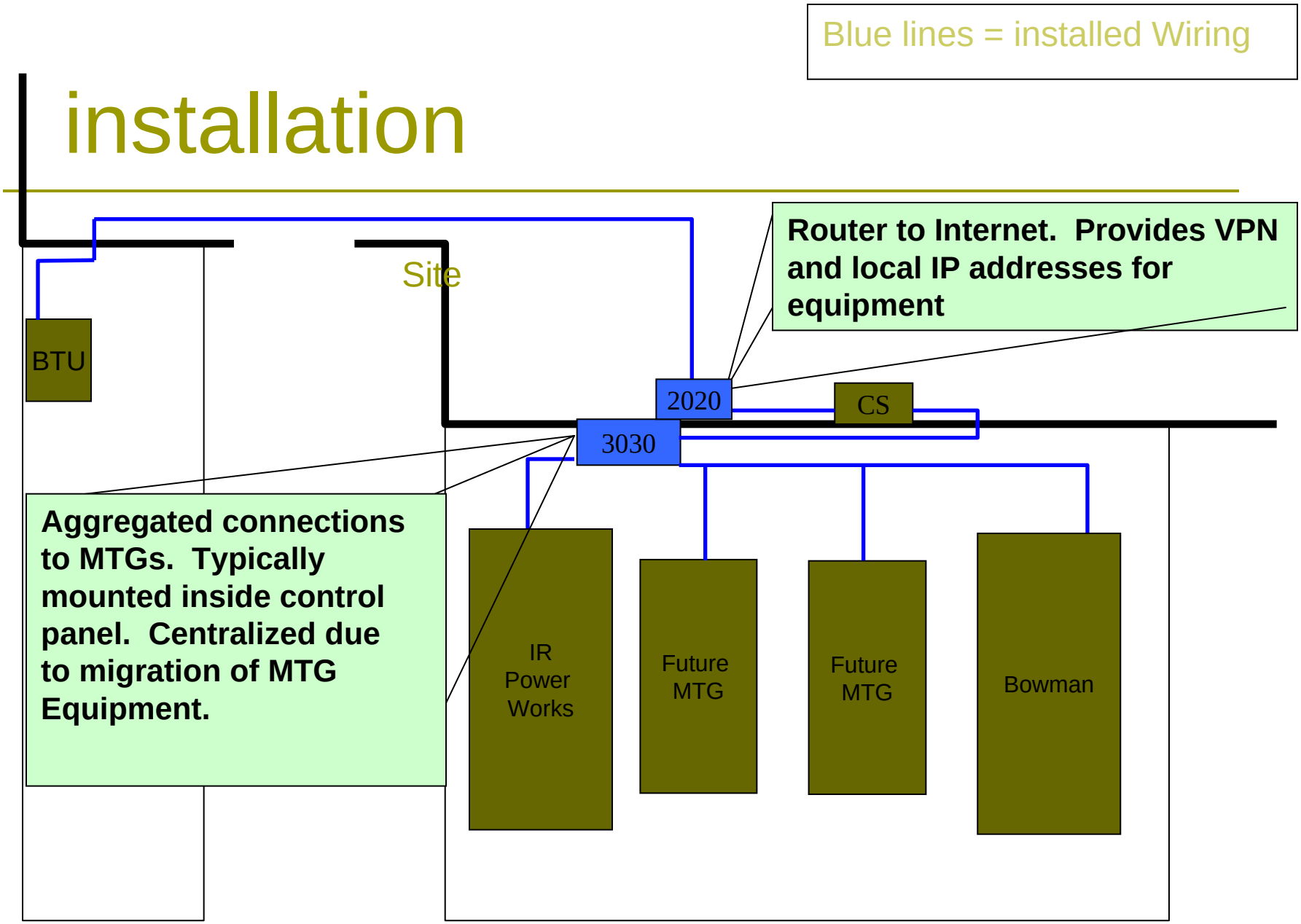
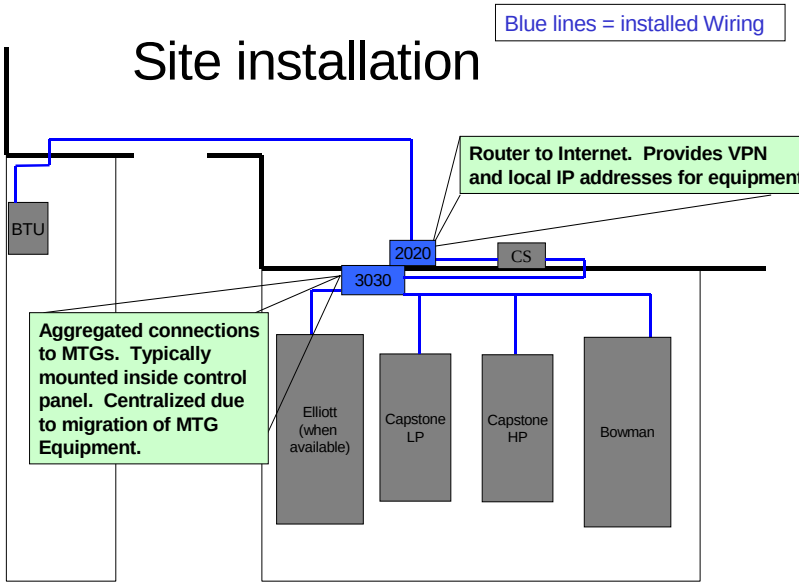
Bow. Data Updated	13:32 on 11/19/2003
State	Idle
Fault	No Fault
Neutral	-0.9 Vdc; 0.4 Irms
% of Rated Output	0 %
Generator Output	0.0 kW; 902429.9 kWh
Engine Speed	0.0 RPM; 0 %
Eng. Inlet Air Temp.	119.8 Deg. F; 51.0 Deg. C
Runtime	15093 Hours
Eng. Encl. Temp.	108.7 Deg. F; 44.0 Deg. C
# of Starts	127
# of Good Starts	66
Recup. Inlet Air Tem	525.2 Deg. F; 277.8 Deg. C
DC Link Voltage	2.0 Volts
Battery Voltage	26.4 Volts
Comb. Inlet Air Temp	179.6 Deg. F; 86.0 Deg. C
Stack Temp.	93.2 Deg. F; 34.0 Deg. C
Oil Temp.	104.0 Deg. F; 40.0 Deg. C
Elec. Encl. Temp.	92.3 Deg. F; 33.0 Deg. C
Software Ver.	854
Oil Pressure	0.1 BAR
Exhaust Temp. 1	509.0 Deg. F; 279.0 Deg. C
Exhaust Temp. 2	525.2 Deg. F; 292.0 Deg. C
Delta Exhaust Temp	-1.8 Deg. F; 13.0 Deg. C
Max. EGT	1142.6 Deg. F; 617.0 Deg. C

installation



“3030” box at SCE MTG Test Bed



Site Location:
Southern California Edison
MTG Test Facility
University of California Irvine, CA.

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Bowman 80 kW CHP at Hydro Quebec

Bowman 80 kW CHP

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