Program to Develop Advances in Combined Heat and Power Systems

NiSource Energy Technologies
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Vice President & Chief Scientist

Why CHP

- Combined Heat and Power (CHP) produces electricity at the point of use and harvests the excess heat for useful purposes to increase efficiency.
  - Electric generation is typically 35% efficient.
  - CHP can increase this efficiency beyond 65%
  - More efficiency means improved use of fuel resources and reduced emissions.

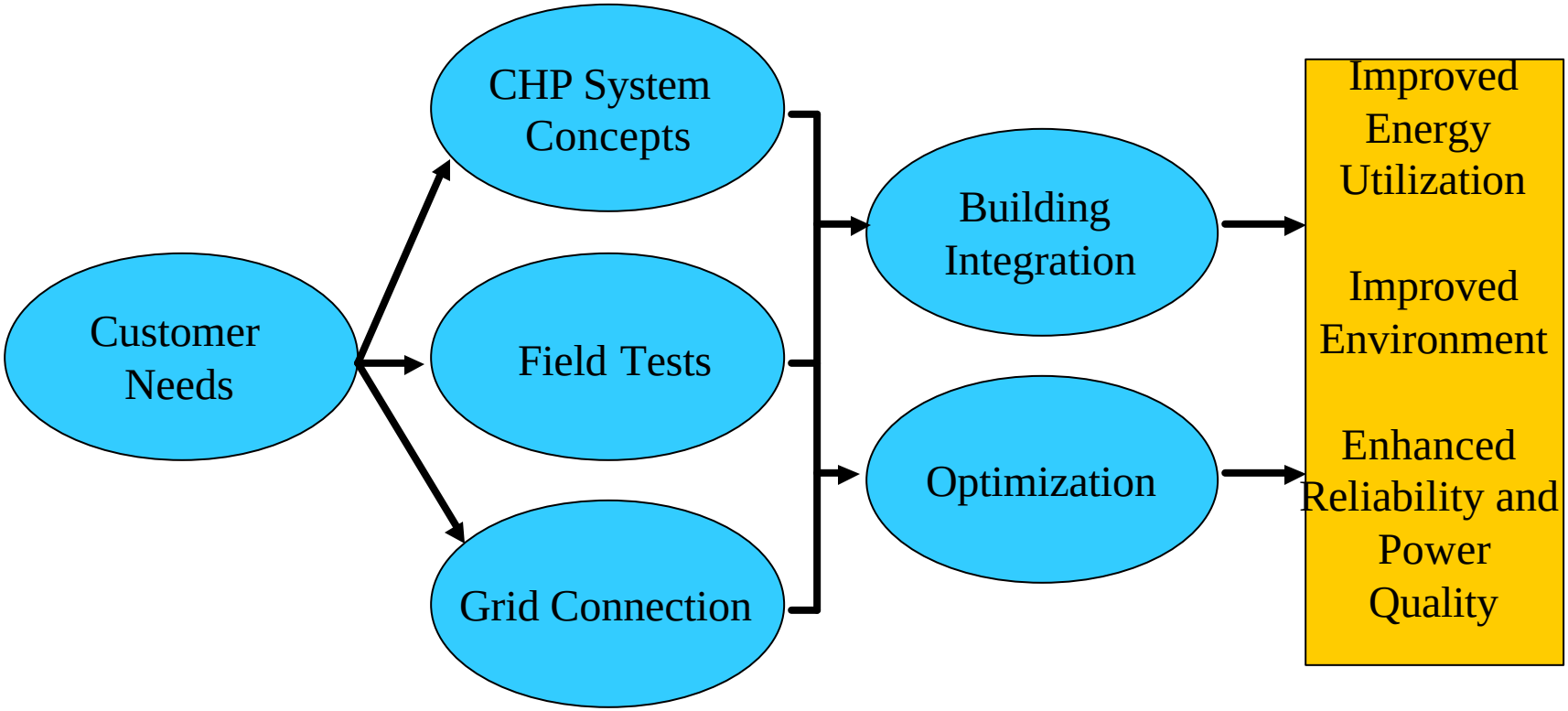
NiSource Territory

Pipeline
Gas Distribution Territory
Bay State Gas Company
Gas Transmission Territory

Ozone Nonattainment County

Figure 1. NiSource Gas Service Territories and Ozone Nonattainment Areas

Project Task Flow



NET CHP Activities

- NiSource Energy Technologies (NET) is a subsidiary of NiSource.
- We have been developing CHP (and BCHP) systems for approximately 6 years.
- We have been testing CHP systems at actual commercial sites for 3 years.
- We are currently at a pre commercial state and are preparing to offer commercial CHP systems.

Current CHP Operating Capabilities

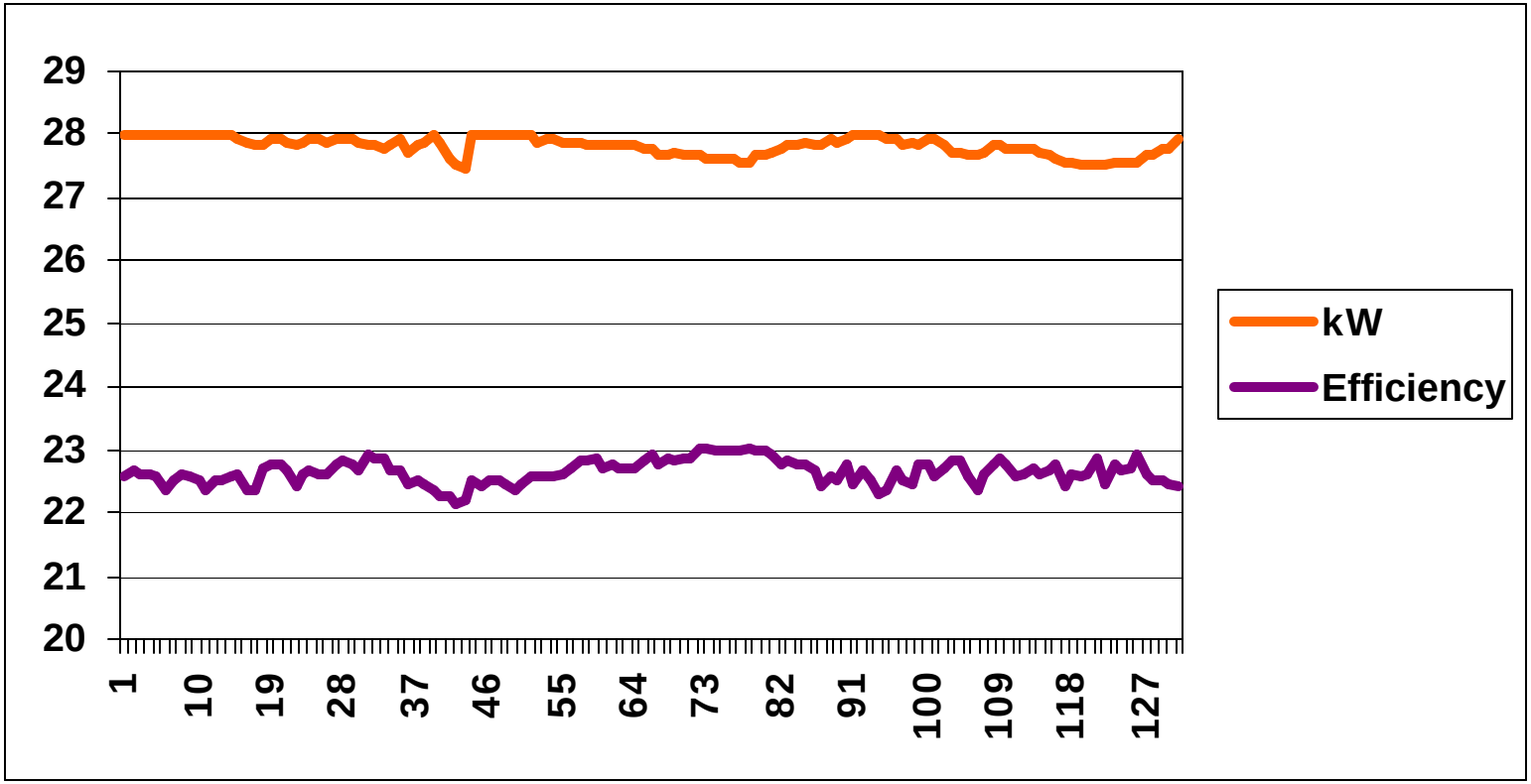
- Produces electricity using a microturbine or other electricity producing device operating on natural gas (other fuels possible)
  - Provides bumpless transition to isolated operation of critical loads on loss of grid power
  - Other generating sources including fuel cells and renewables are under test and development
- Base loaded economic operation
  - Waste heat is collected by proprietary system and used for heating, cooling, and/or dehumidification
  - High efficiency
  - Advanced controls now in development will expand operational and economic capability in BCHP mode.

CHP for Retail Application

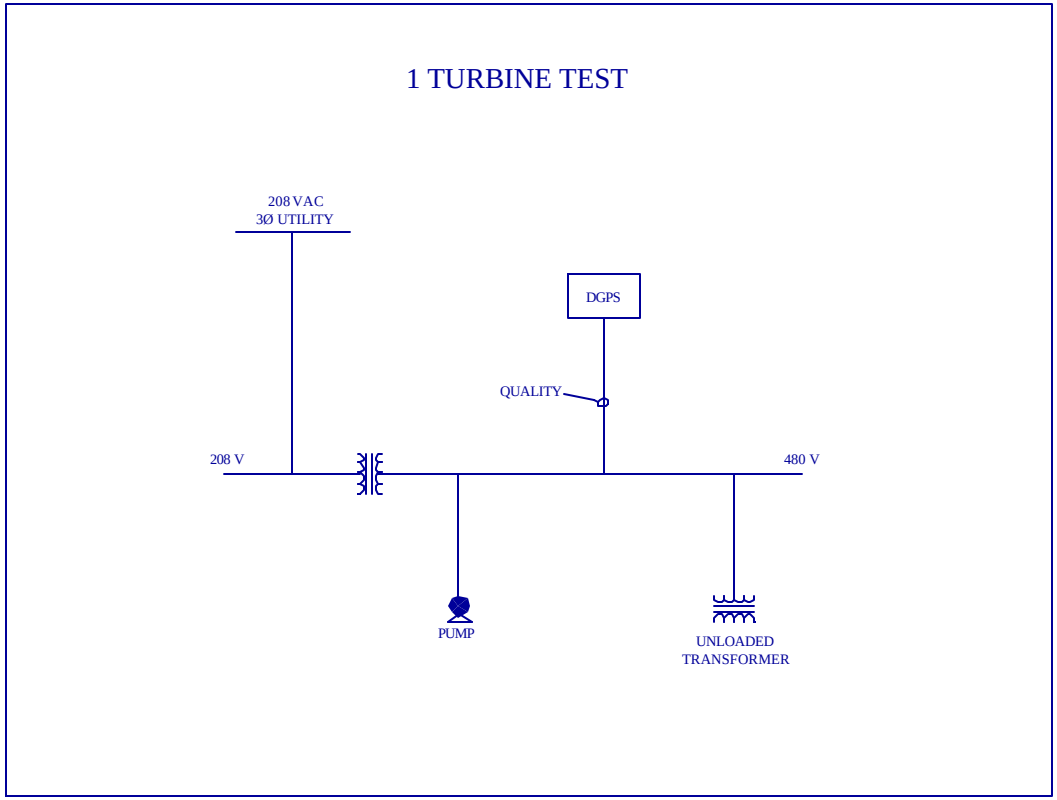
New Refined System

Initial Test System

Turbine Efficiency



Additional Performance Testing

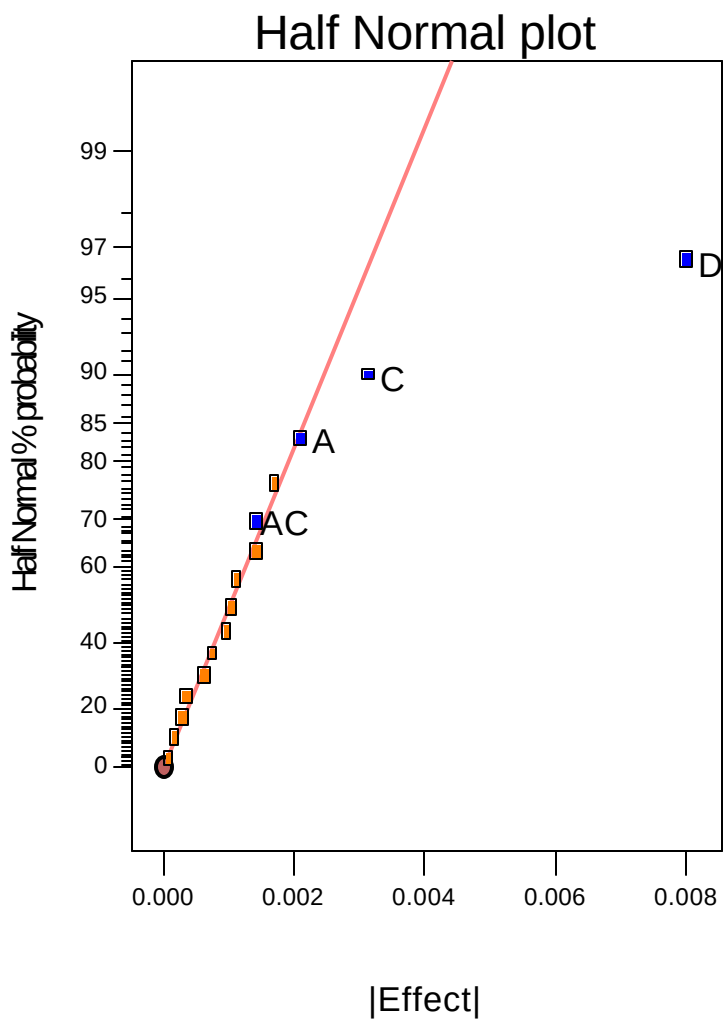


Pump Assembly

Test 1

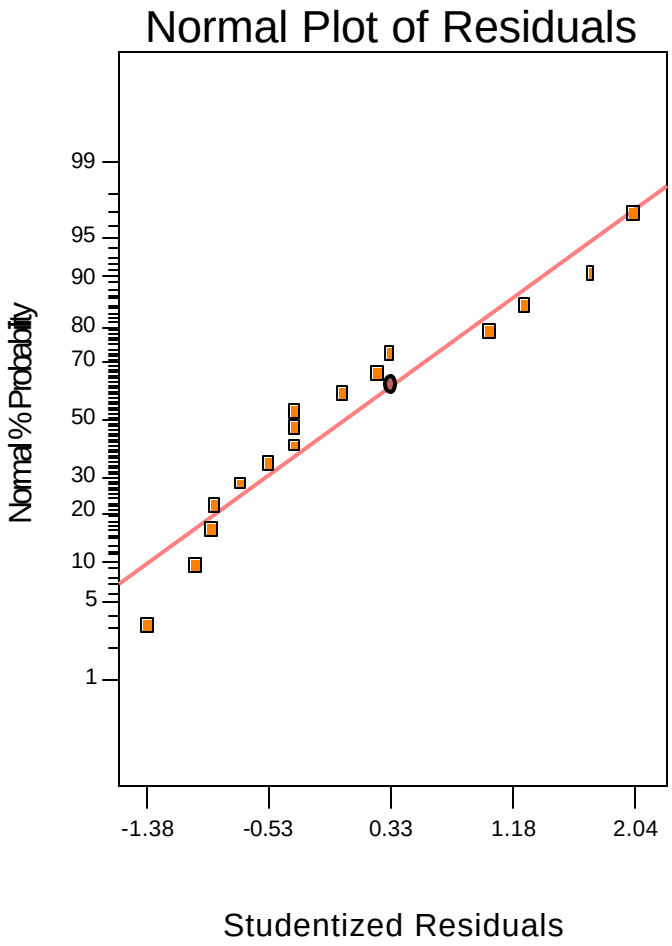
DESIGN-EASE Plot
efficiency

A: Gas Pressure
B: Inductive Load
C: Intake Temp
D: Turbine Output



Test 1

DESIGN-EASE Plot
efficiency

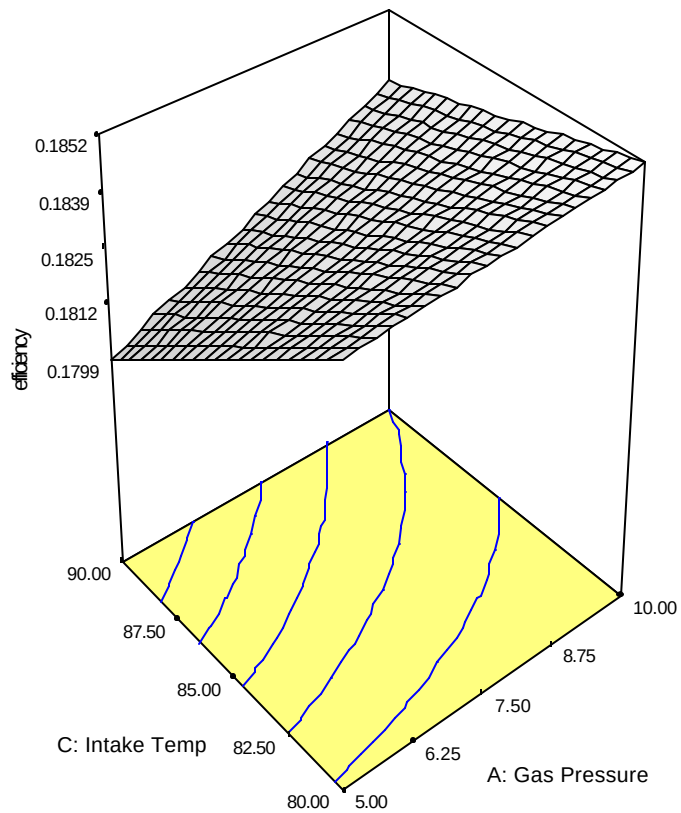


Test 1

DESIGN-EASE Plot

efficiency
X = A: Gas Pressure
Y = C: Intake Temp

Actual Factors
B: Inductive Load = 0.00
D: Turbine Output = 20.00

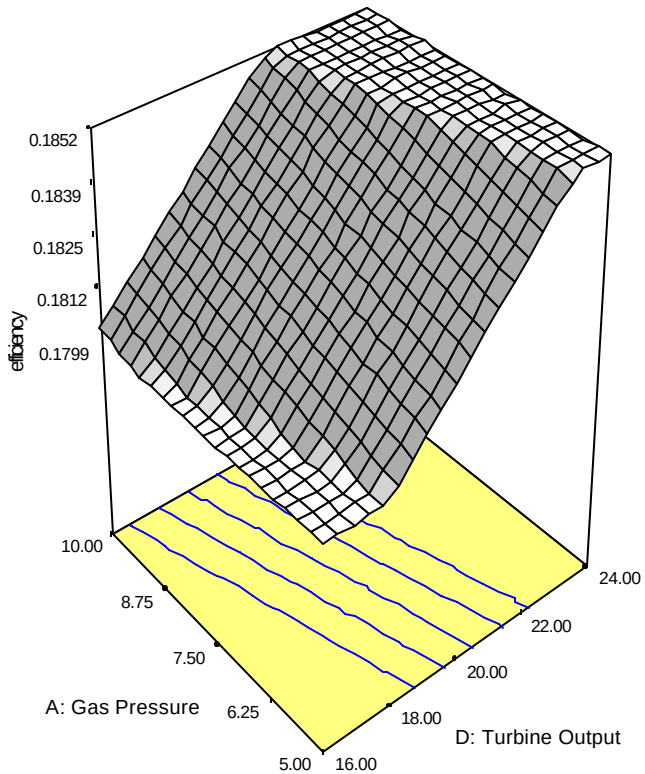


Test 1

DESIGN-EASE Plot

efficiency
X = D: Turbine Output
Y = A: Gas Pressure

Actual Factors
B: Inductive Load = 0.00
C: Intake Temp = 85.00

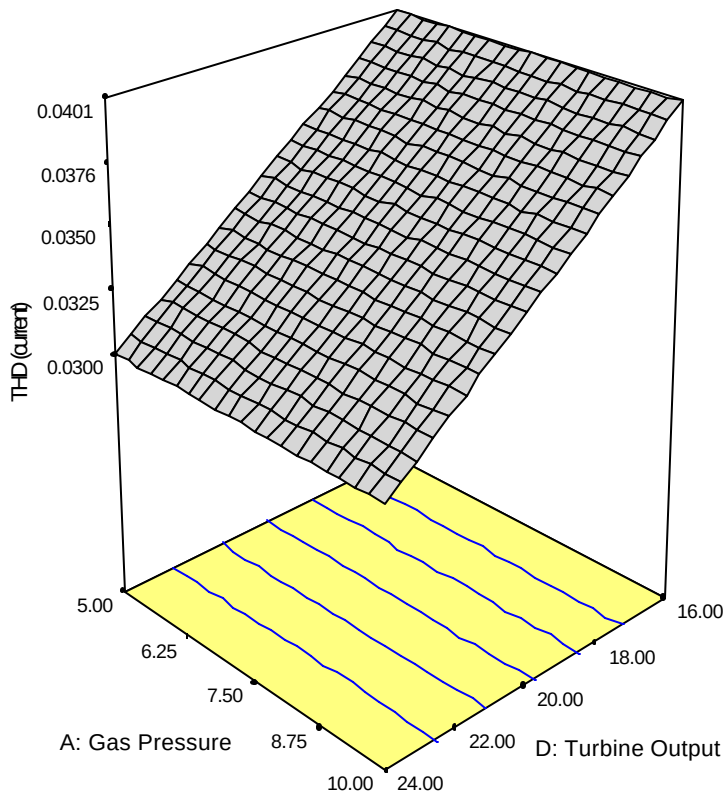


Test 1

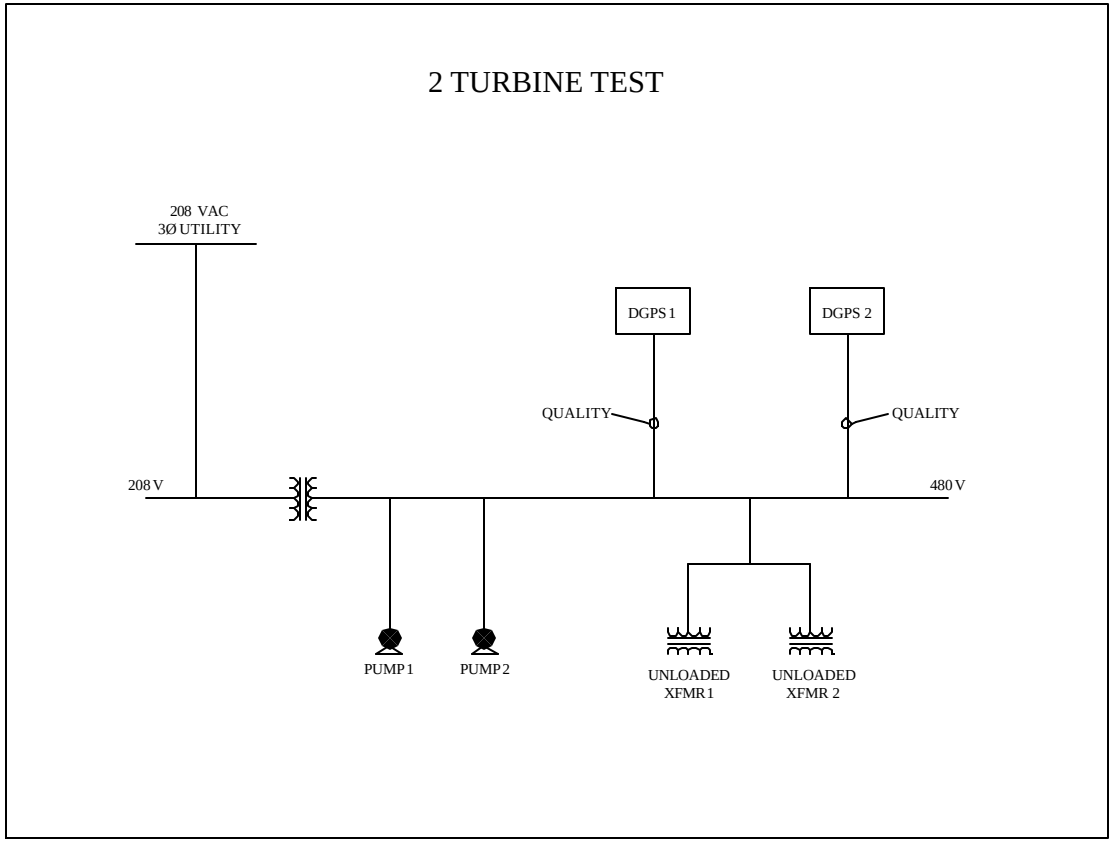
DESIGN-EASE Plot

THD (current)
X = D: Turbine Output
Y = A: Gas Pressure

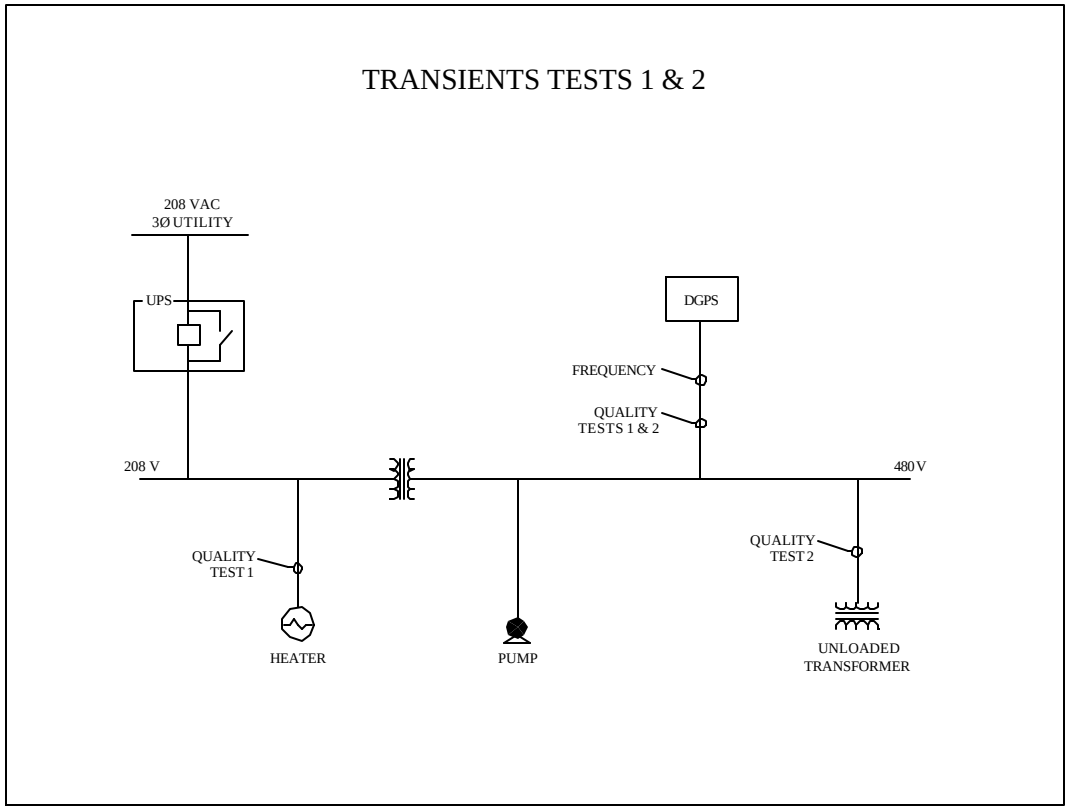
Actual Factors
B: Inductive Load = 0.00
C: Intake Temp = 85.00



Two Turbine Test

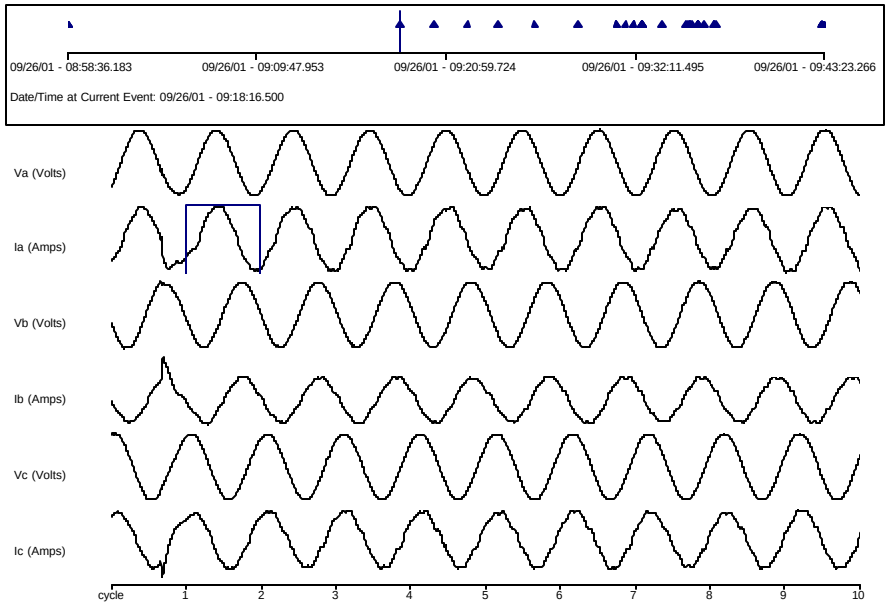


Transient Tests



Transient Tests

Current and Harmonic Distortion for Resistive Transient



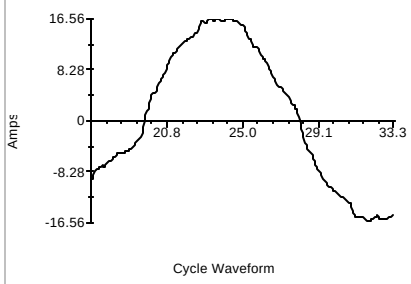
Event: 4 Of 40 — Event Trigger Input 5 Vc Volts (LOWER)

Duration: 21 Cycles — Event Trigger Cycle 1

Time: 09/26/01 09:18:16.500

Input: Ia Amps

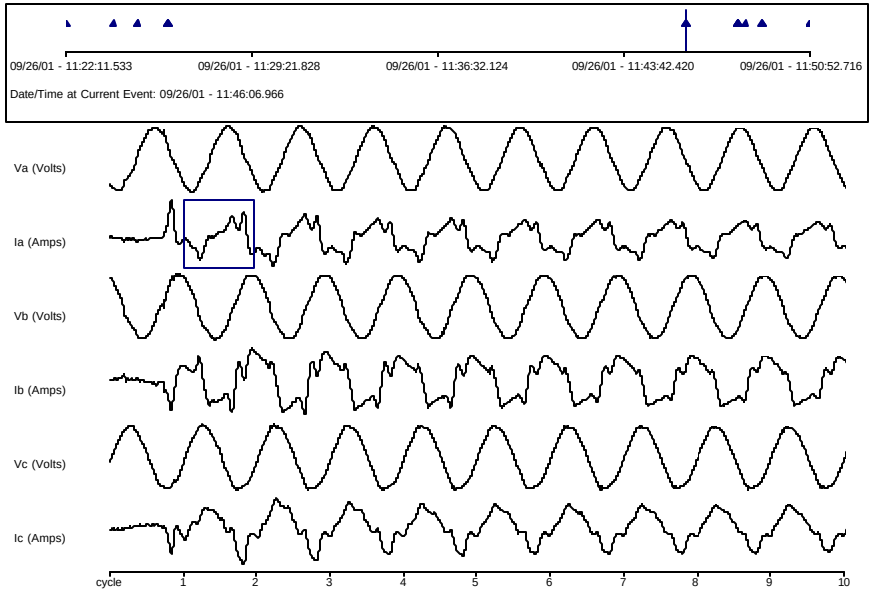
Cycle: 2



Total Harmonic Distortion	11.48 %
Odd Contribution	9.09 %
Even Contribution	7.01 %
RMS Of Fundamental	11.27 A
RMS Of Fund + Harm	11.36 A
K Factor	2.19

Harm	% Of Fund	Amps	Angle	Harm	% Of Fund	Amps	Angle
Fund	100.00	11.3	0°	2	3.95	0.4	176°
3	4.06	0.5	243°	4	3.89	0.4	269°
5	6.78	0.8	300°	6	2.79	0.3	14°
7	1.78	0.2	334°	8	1.41	0.2	93°
9	1.24	0.1	185°	10	0.56	0.1	264°
11	3.07	0.3	310°	12	1.48	0.2	17°
13	0.86	0.1	21°	14	0.76	0.1	131°
15	0.91	0.1	200°	16	1.07	0.1	272°
17	1.32	0.1	281°	18	1.05	0.1	356°
19	0.25	0.0	143°	20	0.32	0.0	166°
21	0.44	0.0	169°	22	0.61	0.1	297°
23	0.81	0.1	255°	24	0.82	0.1	346°
25	0.53	0.1	72°	26	0.45	0.1	142°
27	0.45	0.1	190°	28	0.64	0.1	249°
29	0.30	0.0	285°	30	0.15	0.0	327°
31	0.47	0.1	71°	32	0.27	0.0	126°
33	0.28	0.0	232°	34	0.50	0.1	279°
35	0.28	0.0	330°	36	0.43	0.0	28°
37	0.38	0.0	44°	38	0.04	0.0	218°
39	0.40	0.0	194°	40	0.35	0.0	301°
41	0.27	0.0	315°	42	0.46	0.1	350°
43	0.10	0.0	320°	44	0.26	0.0	160°
45	0.19	0.0	178°	46	0.52	0.1	257°
47	0.28	0.0	324°	48	0.16	0.0	47°
49	0.09	0.0	84°	50	0.29	0.0	155°
51	0.22	0.0	205°	52	0.21	0.0	291°
53	0.17	0.0	356°	54	0.20	0.0	45°
55	0.18	0.0	118°	56	0.27	0.0	164°
57	0.17	0.0	220°	58	0.09	0.0	303°
59	0.18	0.0	328°	60	0.18	0.0	51°
61	0.22	0.0	123°	62	0.12	0.0	162°
63	0.18	0.0	239°				

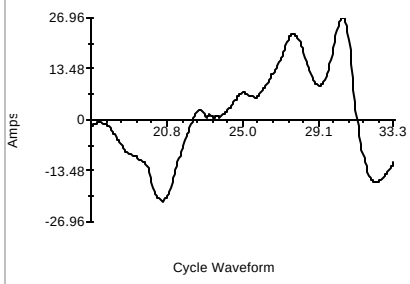
Current and Harmonic Distortion for Inductive Transient (Grid Isolated)



Event: 9 Of 17
Duration: 21 Cycles

Event Trigger Input 6 Ic Amps (THD)
Event Trigger Cycle 1

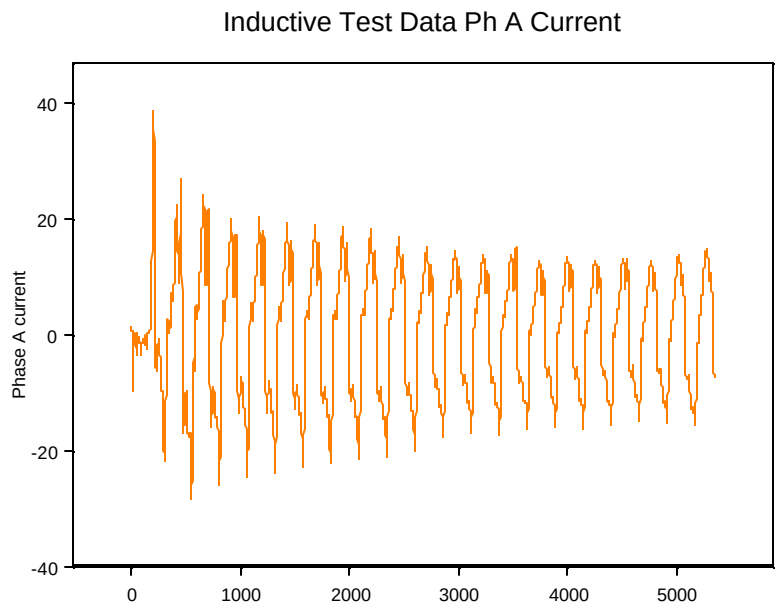
Time:	09/26/01 11:46:06.967
Input:	Ia Amps
Cycle:	2

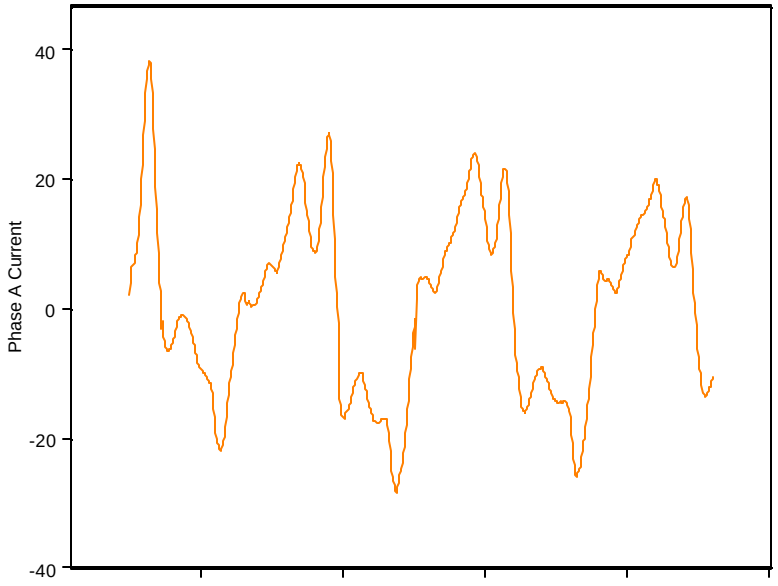


Total Harmonic Distortion	68.80 %
Odd Contribution	44.14 %
Even Contribution	52.77 %
RMS Of Fundamental	10.44 A
RMS Of Fund + Harm	12.70 A
K Factor	9.73

Harm	% Of Fund	Amps	Angle	Harm	% Of Fund	Amps	Angle
Fund	100.00	10.4	0°	2	14.02	1.5	242°
3	36.29	3.8	88°	4	36.83	3.8	205°
5	22.52	2.4	51°	6	33.43	3.5	265°
7	5.21	0.5	118°	8	7.94	0.8	14°
9	7.40	0.8	207°	10	2.56	0.3	38°
11	5.01	0.5	233°	12	5.15	0.5	54°
13	0.48	0.1	19°	14	0.05	0.0	338°
15	1.25	0.1	59°	16	1.65	0.2	219°
17	2.14	0.2	47°	18	2.28	0.2	190°
19	1.12	0.1	326°	20	0.93	0.1	182°
21	0.51	0.1	308°	22	1.00	0.1	86°
23	1.63	0.2	215°	24	1.02	0.1	322°
25	0.88	0.1	179°	26	0.78	0.1	334°
27	0.57	0.1	90°	28	0.70	0.1	257°
29	0.81	0.1	22°	30	0.61	0.1	153°
31	0.98	0.1	344°	32	0.83	0.1	164°
33	0.63	0.1	311°	34	0.59	0.1	60°
35	0.15	0.0	160°	36	0.63	0.1	21°
37	0.74	0.1	131°	38	0.86	0.1	307°
39	1.04	0.1	111°	40	0.60	0.1	279°
41	0.67	0.1	85°	42	0.57	0.1	195°
43	0.23	0.0	356°	44	0.39	0.0	147°
45	0.60	0.1	263°	46	0.58	0.1	65°
47	0.49	0.1	221°	48	0.42	0.0	46°
49	0.58	0.1	183°	50	0.34	0.0	312°
51	0.32	0.0	107°	52	0.42	0.0	251°
53	0.47	0.0	56°	54	0.43	0.0	210°
55	0.42	0.0	355°	56	0.37	0.0	139°
57	0.38	0.0	281°	58	0.42	0.0	76°
59	0.37	0.0	238°	60	0.40	0.0	37°
61	0.41	0.0	177°	62	0.35	0.0	328°
63	0.37	0.0	120°				

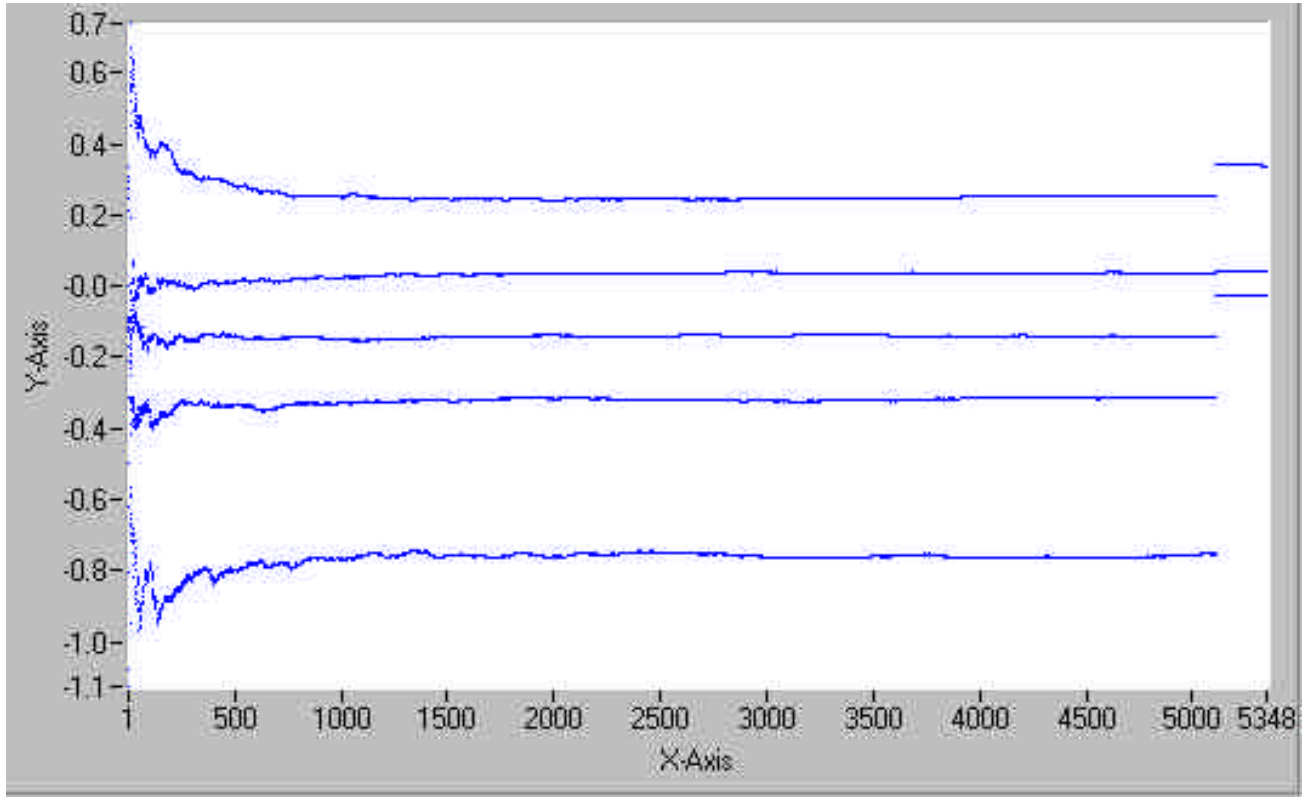
Inductive Transient Test (Grid Isolated)



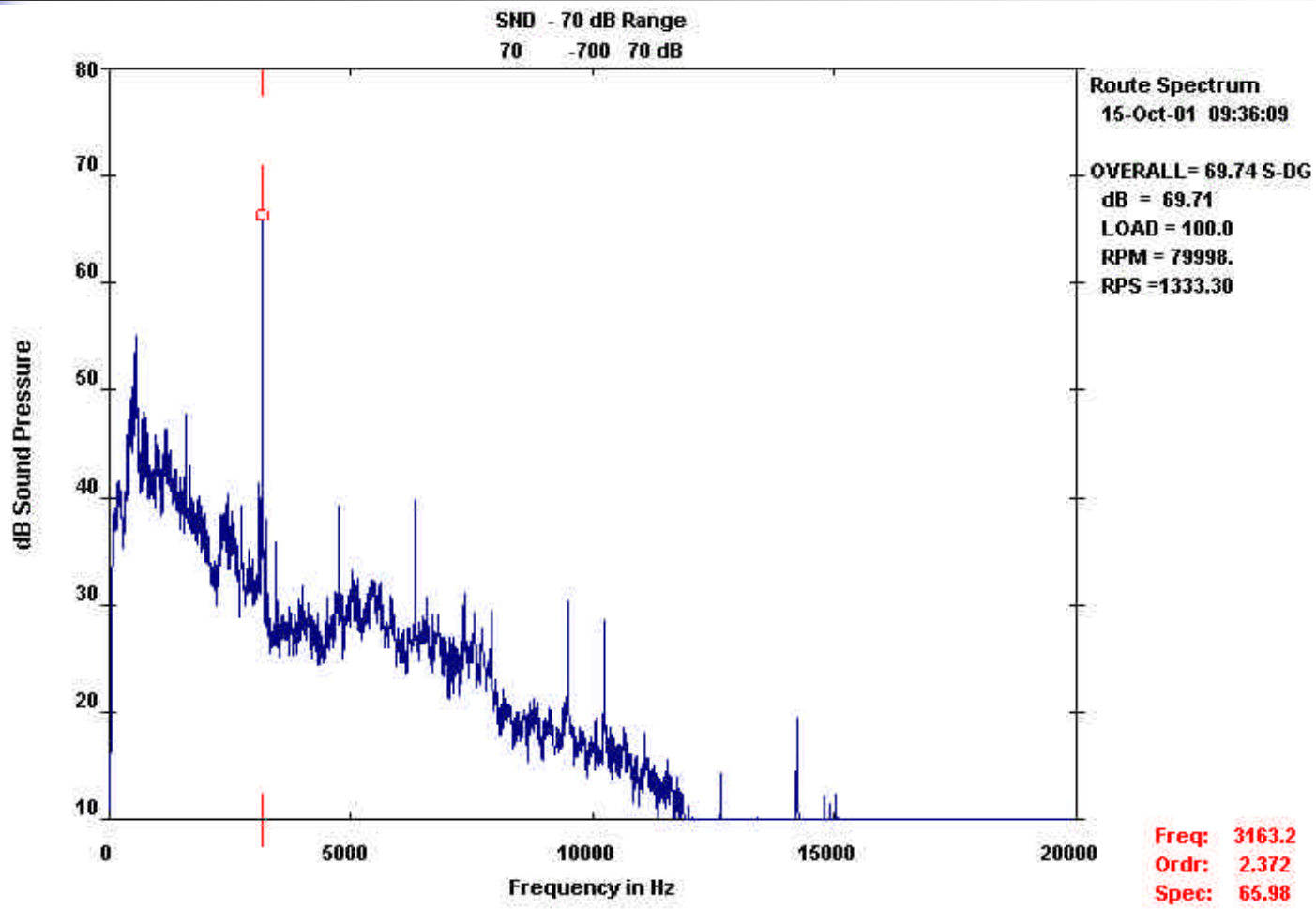


Inductive Transient Test (Grid Isolated)

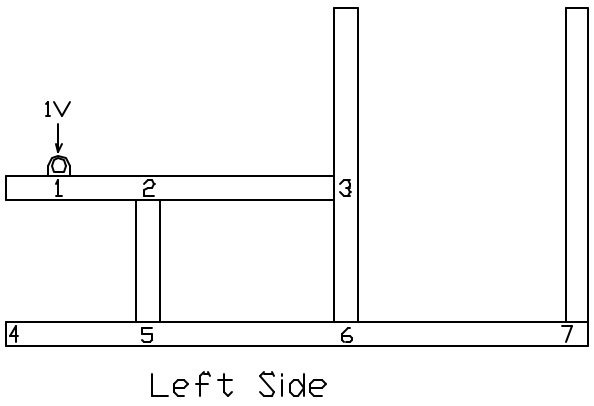
Lyapunov Spectrum Phase A Current
Inductive Transient

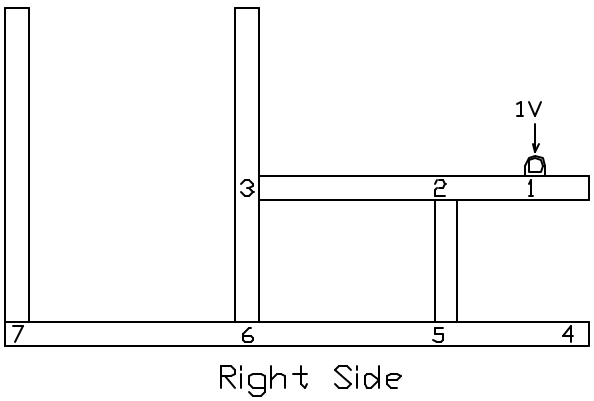


Acoustic Measurements

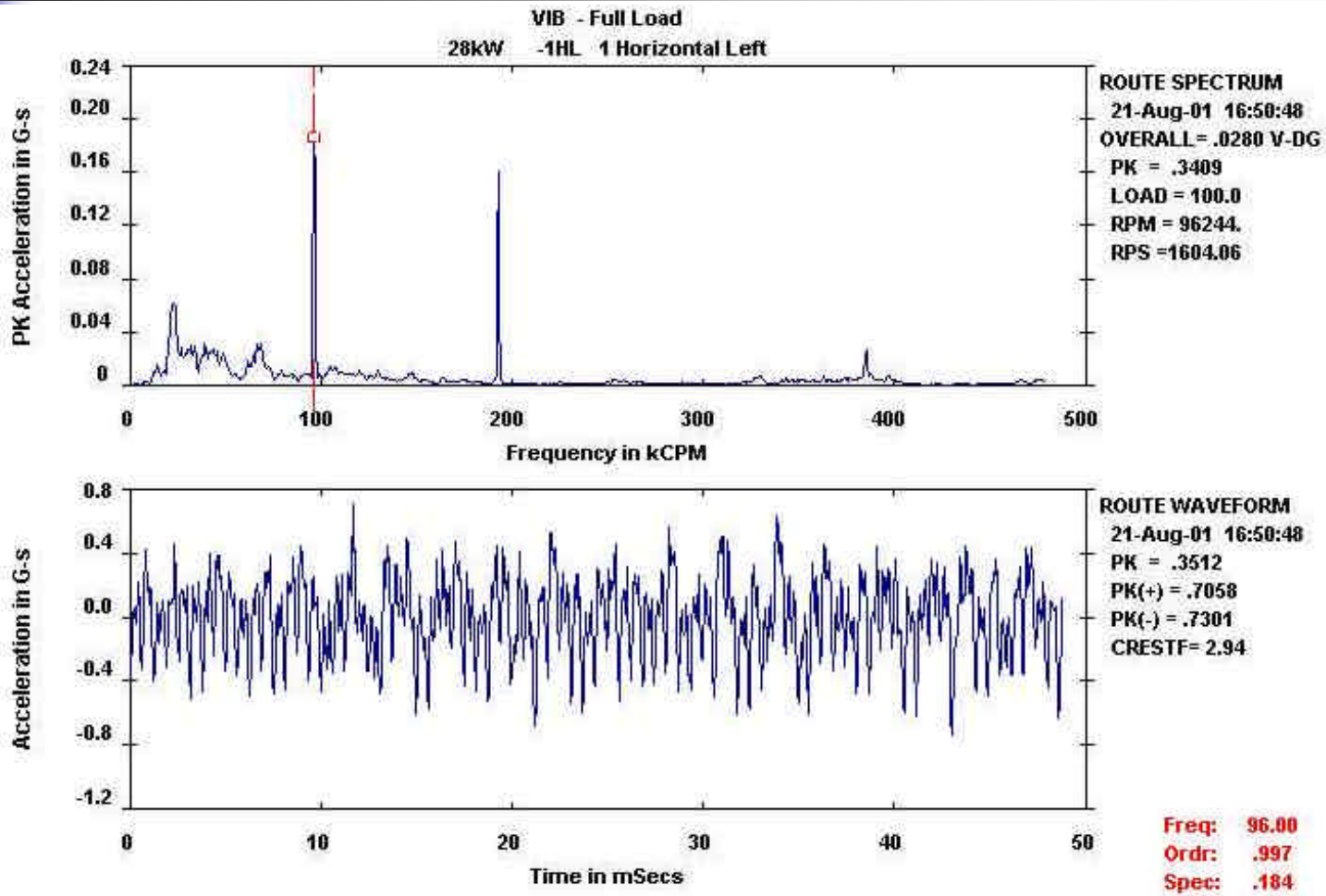


Vibration Measurements





Vibration Measurements



Basic Test Program

- Three-phase, multi-year research and development effort to advance distributed power development, deployment, and integration.
- Develop, test, and optimize several (electric/natural gas/ renewable energy) stand-alone distributed power systems.
- Develop and initiate laboratory and field tests, methodologies, controls (including command, communications, monitoring, efficiency, and heat rate).

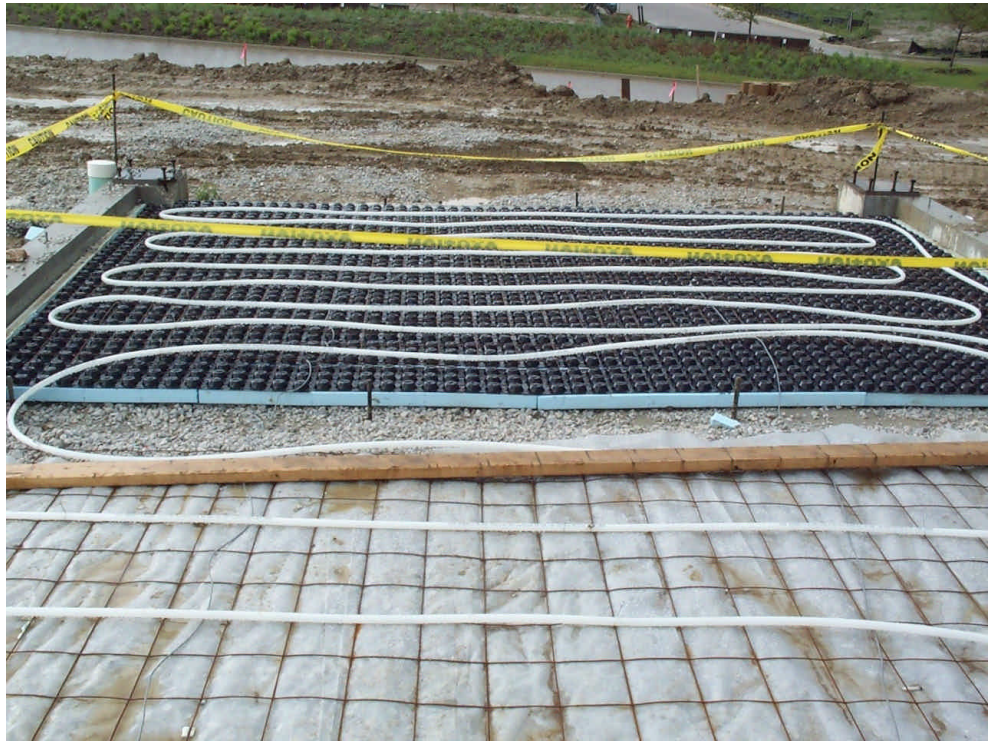
CHP Package for Hotel Industry

- Three year program to develop BCHP systems for use in hotel industry
- Will include advanced BCHP concepts including intelligent controls and storage.
- Electricity will be produced from micro turbines, fuel cells, and renewables. Heat utilized for various purposes.
- Complete energy package for integration into building

Hotel During Construction

Piping

Front Lobby Piping



Piping Installation

Piping Header in Hotel

Trench to Hotel

CHP Building