Lessons Learned and Performance of the CHP Integration Test Center at the University of Maryland

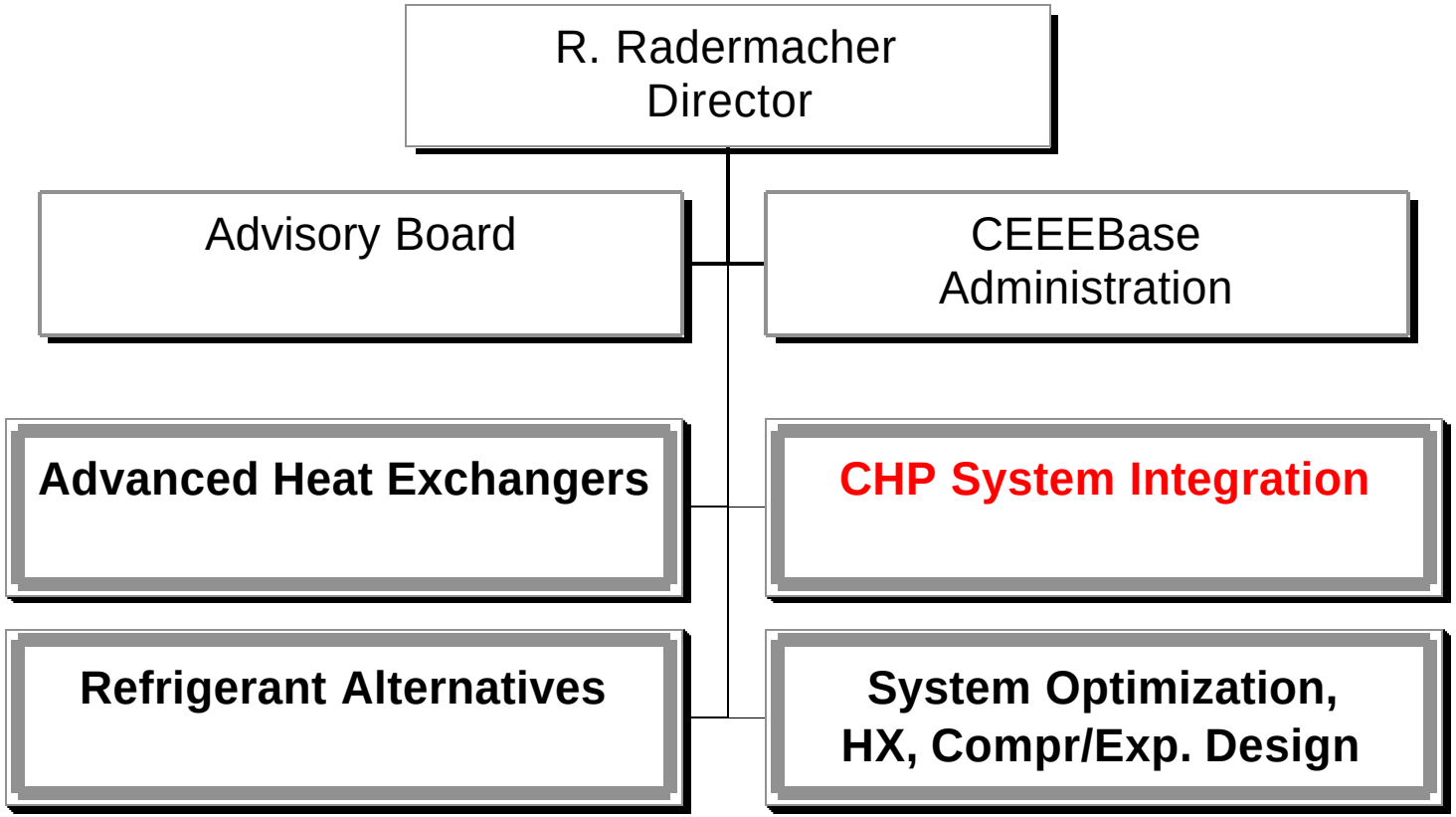
DOE/CETC/CANDRA
Workshop on Microturbine Applications
January 17, 2002

Reinhard Radermacher, University of Maryland

CHP
For Buildings

Center for Environmental Energy Engineering

CEEE Organization



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CEEE Partners

1	ATEC
2	ATS
3	Baltimore Air Coil
4	BG&E
5	Brazeway
6	Broad
7	Capron Engineering
8	Capstone
9	Carrier
10	Coca Cola
11	Copeland
12	CPI Engineering
13	Daikin
14	Denso
15	DOE/ORNL
16	General Motors

17	Goettl
18	Halla
19	Heatcraft
20	Hitachi
21	Honeywell
22	Hydro Aluminum
23	ITRI
24	LG Electronics
25	Matsushita
26	Modine
27	Naval Res. Lab.
28	PEPCO
29	RMF Engineering Inc.
30	Sabroe
31	Samsung Electronics
32	Sanden
33	Sanyo

34	Swales
35	Tecumseh
36	Thermal Components
37	Thermo King
38	Trane
39	Tridium
40	Trion
41	US Army
42	Visteon
43	Washington Gas Light
44	Wieland
45	Wolverine
46	Wright Patterson AFB
47	York

Trigen

Thanks !

University of Maryland 1856

CEEE Center for Environmental Energy Engineering

ornl Oak Ridge National Laboratory

DAIKIN

Honeywell

Baltimore Aircoil

pepco

RMF Engineering, Inc. Professional Engineers

TRION

EPRI

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Washington Gas

ATS Stulz Air Technology Systems, Inc.

Capstone

TRIDIUM

EPA United States Environmental Protection Agency

BROAD AIR CONDITIONING
远大空调有限公司

CAPRON

GOETTL AIR CONDITIONING

TRIGEN

KATHABAR

Professional Collaboration

- ORNL – Sensors (CO_2 and Humidity)
- PNNL – Whole Building Diagnostician
- NREL – Liquid Desiccant Components
- Energy Storage (DOE, Energetics, NRECA, Sandia – Distributed Energy Technology Simulator)
- Southern Research Institute, EPA, Honeywell – Independent Verification of Micro-Turbine Performance and Emissions
- ORNL – Integrated System Performance Evaluation

DOE's CHP Integration Test Center at the University of Maryland

This integration facility serves as a platform to:

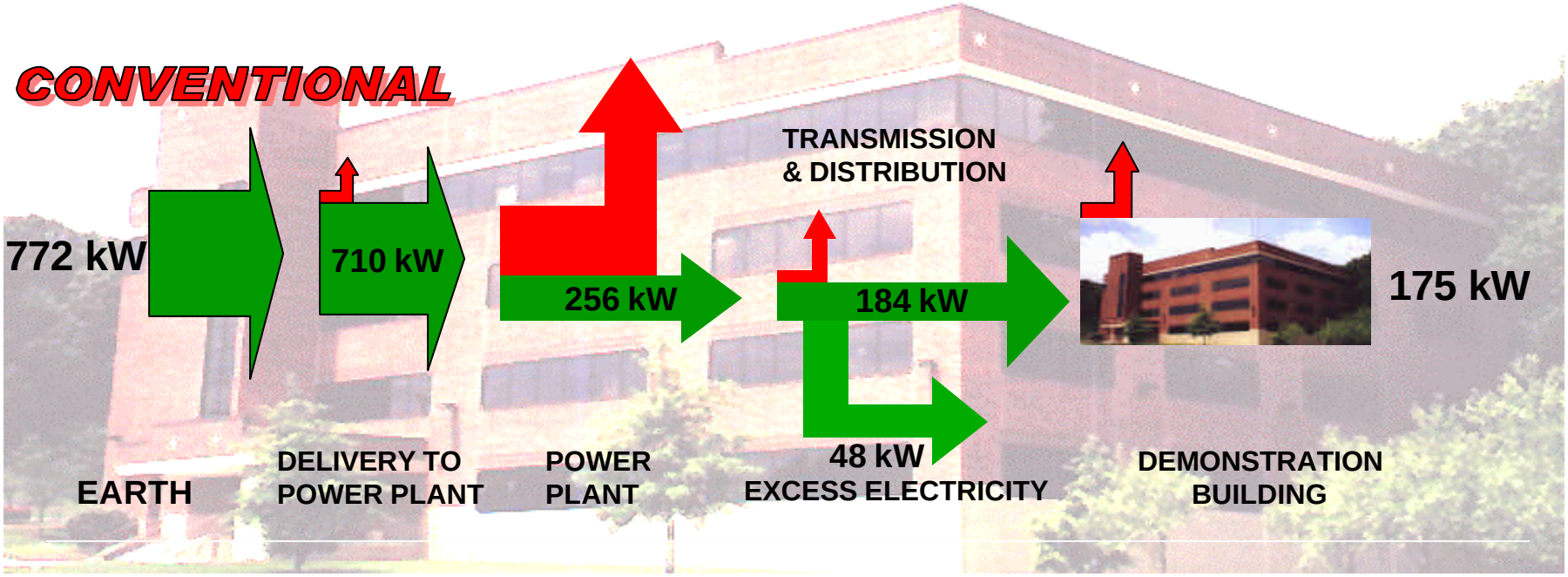
- **Integrate equipment into CHP systems**
- **Integrate CHP systems into commercial buildings**
- **Test advanced control systems**
- **Provide essential technical knowledge to manufacturing partners**

BCHP PROGRAM IMPACT

- **COMMERCIAL BUILDINGS ACCOUNT FOR 36% OF US ENERGY CONSUMPTION (3.6 BILLION MWh)**
- **AIR CONDITIONING IS LARGE, OFTEN THE LARGEST ENERGY CONSUMER IN BUILDING**
- **95 % OF BUILDINGS HAVE ELECTRIC AIR CONDITIONING**

BCHP Research Consortium

Research and Demonstrate Benefits of System Integration



By using waste heat: **30% Energy Savings**
45% CO_2 Emission Reduction

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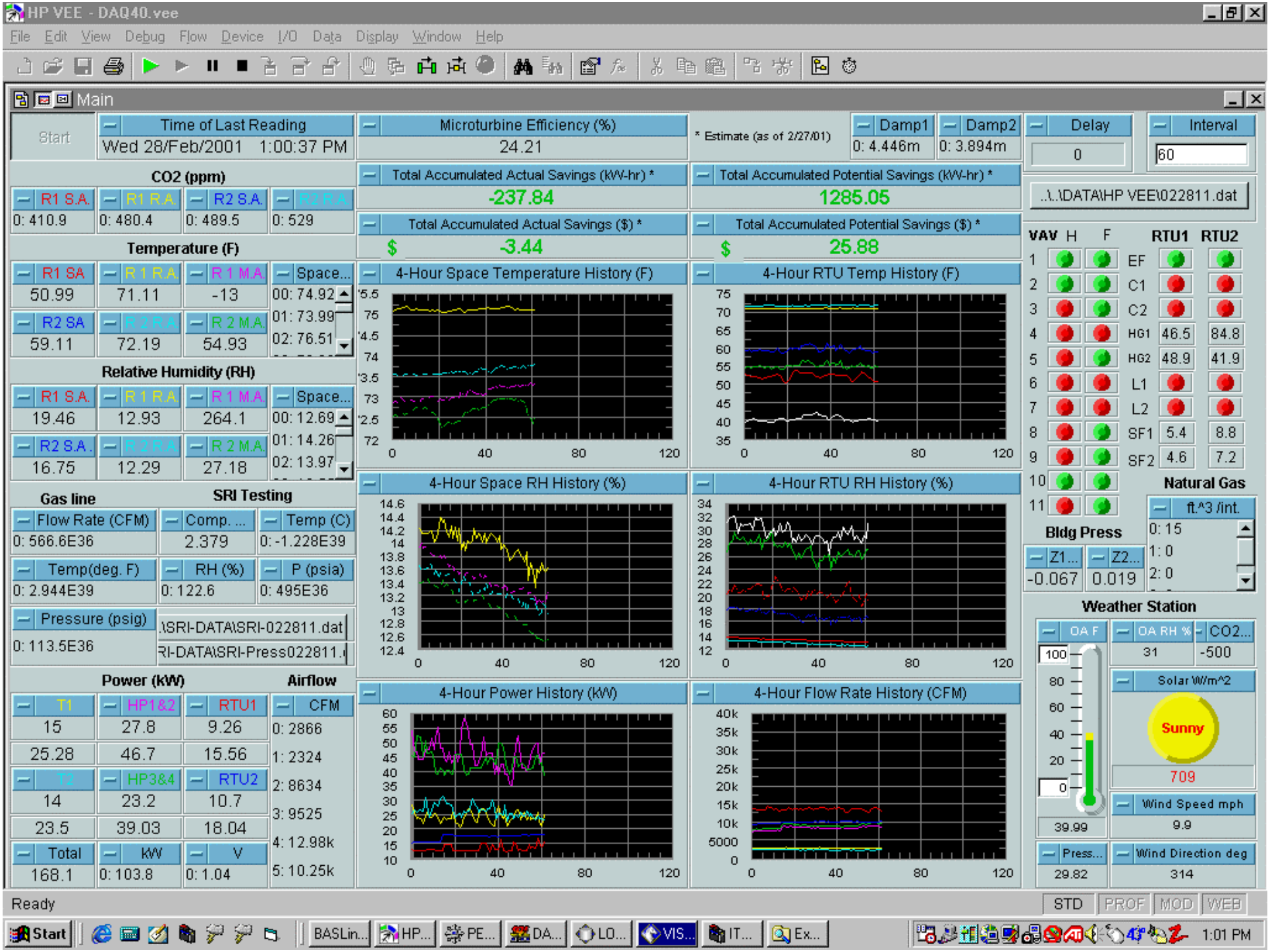
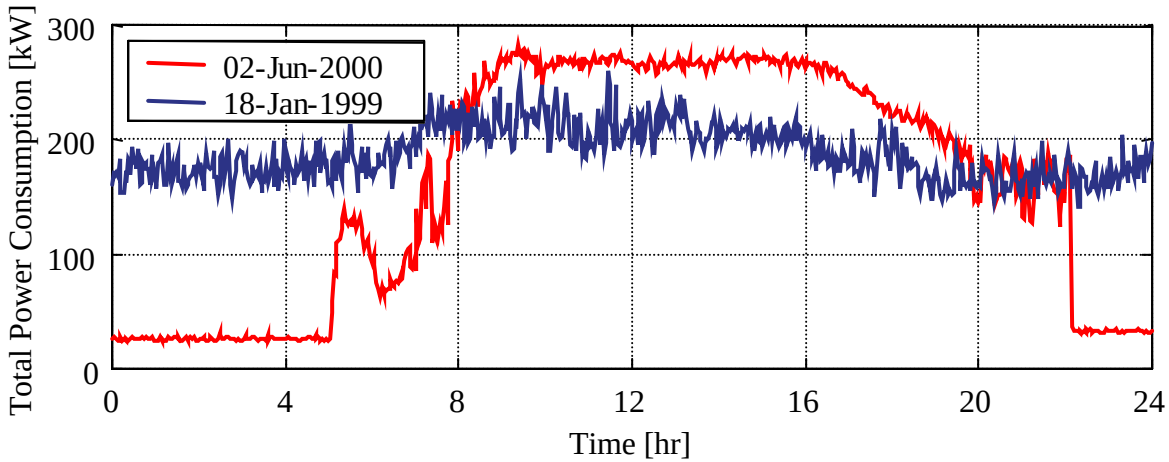
DEMONSTRATION BUILDING

- TYPICAL, MEDIUM SIZE OFFICE BUILDING, 51,000 FT^2,
- 4 FLOORS, 2 ZONES
- 90-TON ROOF TOP UNIT FOR EACH ZONE
- COOLING ALL YEAR
- ECONOMIZER CYCLE
- VAV WITH ELECTRIC REHEAT
- LOW LEVEL CONTROLS
- GAS RARELY USED
- ELECTRIC ~300 kW PEAK
- 10 YEARS OLD, 200 OCCUPANTS


HP VEE - DAQ40.vee
File Edit View Debug Flow Device I/O Data Display Window Help
Main
Start
Time of Last Reading
Wed 28/Feb/2001 1:00:37 PM
Microturbine Efficiency (%)
24.21
* Estimate (as of 2/27/01)
Damp1
0: 4.446m
Damp2
0: 3.894m
Delay
0
Interval
60
..\..\DATA\HP VEE\022811.dat
CO2 (ppm)
R1 S.A. 0: 410.9
R1 R.A. 0: 480.4
R2 S.A. 0: 489.5
R2 R.A. 0: 529
Total Accumulated Actual Savings (kW-hr) *
-237.84
Total Accumulated Potential Savings (kW-hr) *
1285.05
Total Accumulated Actual Savings ($) *
$ -3.44
Total Accumulated Potential Savings ($) *
$ 25.88
Temperature (F)
R1 SA 50.99
R1 R.A. 71.11
R1 M.A. -13
Space...
00: 74.92
01: 73.99
02: 76.51
R2 SA 59.11
R2 R.A. 72.19
R 2 M.A. 54.93
4-Hour Space Temperature History (F)
4-Hour RTU Temp History (F)
Relative Humidity (RH)
R1 S.A. 19.46
R1 R.A. 12.93
R1 M.A. 264.1
Space...
00: 12.69
01: 14.26
02: 13.97
R2 S.A. 16.75
R2 R.A. 12.29
R 2 M.A. 27.18
4-Hour Space RH History (%)
4-Hour RTU RH History (%)
Gas line
SRI Testing
Flow Rate (CFM) 0: 566.6E36
Comp. ... 2.379
Temp (C) 0: -1.228E39
Temp(deg. F) 0: 2.944E39
RH (%) 0: 122.6
P (psia) 0: 495E36
Pressure (psig) 0: 113.5E36
\SRI-DATA\SRI-022811.dat
RI-DATA\SRI-Press022811.
Power (kW)
Airflow
T1 15 25.28
HP1&2 27.8 46.7
RTU1 9.26 15.56
CFM
0: 2866
1: 2324
2: 8634
3: 9525
4: 12.98k
5: 10.25k
T2 14 23.5
HP3&4 23.2 39.03
RTU2 10.7 18.04
Total 168.1
kW 0: 103.8
V 0: 1.04
4-Hour Power History (kW)
4-Hour Flow Rate History (CFM)
VAV H F
RTU1 RTU2
1 EF
2 C1
3 C2
4 HG1 46.5 84.8
5 HG2 48.9 41.9
6 L1
7 L2
8 SF1 5.4 8.8
9 SF2 4.6 7.2
10
11
Natural Gas
ft.^3 /int.
0: 15
1: 0
2: 0
Bldg Press
Z1... -0.067
Z2... 0.019
Weather Station
OA F 39.99
OA RH % 31
CO2... -500
Solar W/m^2
Sunny
709
Wind Speed mph 9.9
Press... 29.82
Wind Direction deg 314
Ready
STD PROF MOD WEB
Start
BASLin... HP... PE... DA... LO... VIS... IT... Ex...
1:01 PM

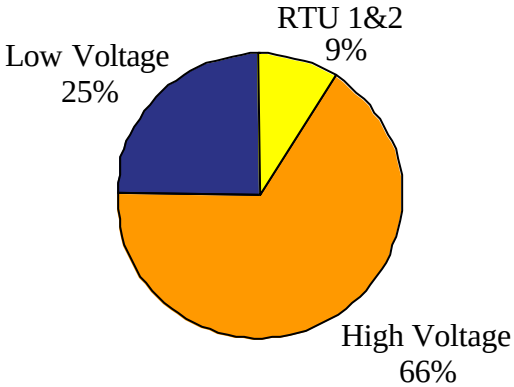
Building Performance

Electric Load Profile



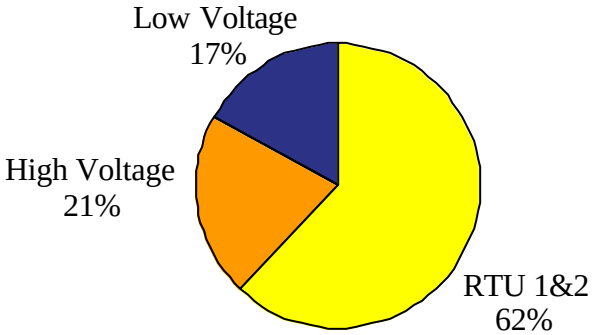
Power Consumption by Type

Winter



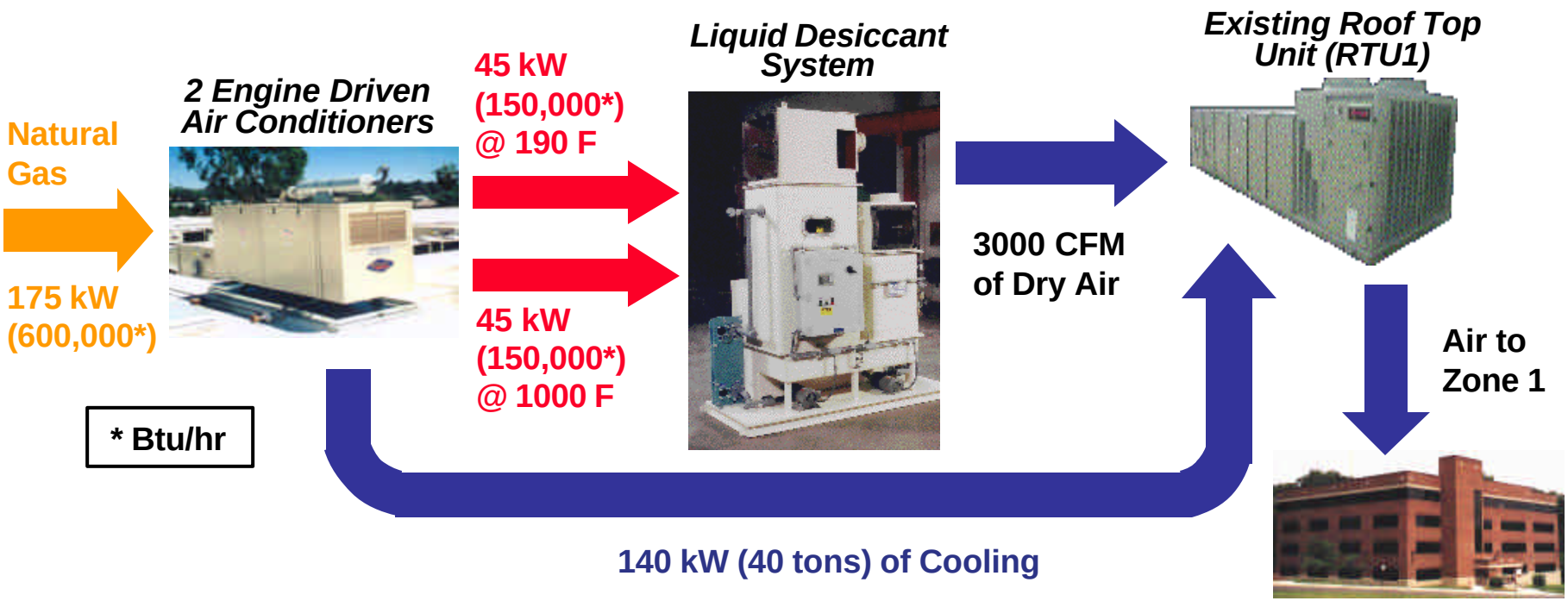
18-Jan-2000

Summer



02-Jun-2000

1ST CHP SYSTEM



- Engine Jacket Water & Exhaust Used to Regenerate Desiccant
- Liquid desiccant waste heat driven
- Overall efficiency up to 80 %

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1ST CHP SYSTEM Engine Units

Efficiency w/o Heat Recovery (Assumed)

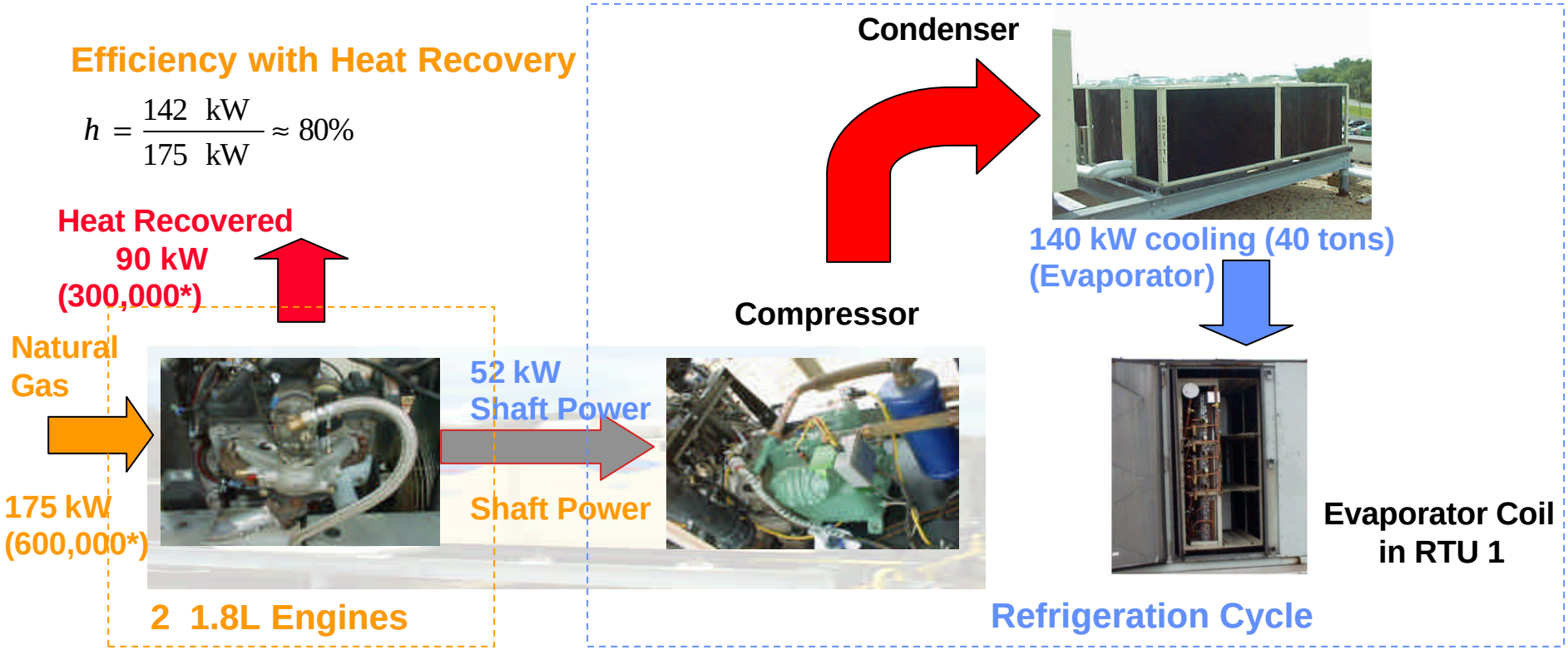
$$h = \frac{52\ \text{kW}}{175\ \text{kW}} \approx 30\%$$

Efficiency with Heat Recovery

$$h = \frac{142\ \text{kW}}{175\ \text{kW}} \approx 80\%$$

COP of Refrigeration Cycle

$$\text{COP} = \frac{140\ \text{kW}}{52\ \text{kW}} \approx 2.7\ (4.6\ in 1^{st}\ stage)$$



* Btu/hr

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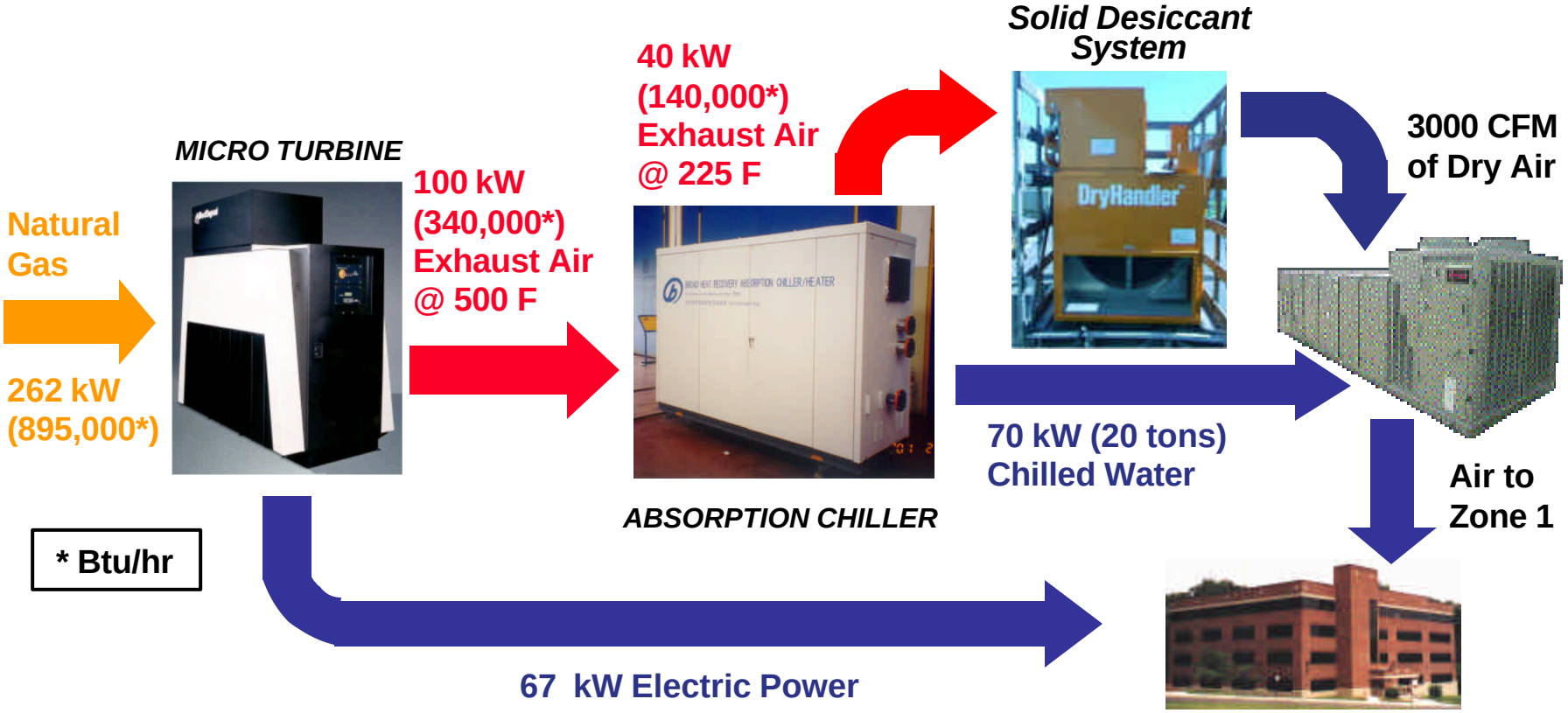
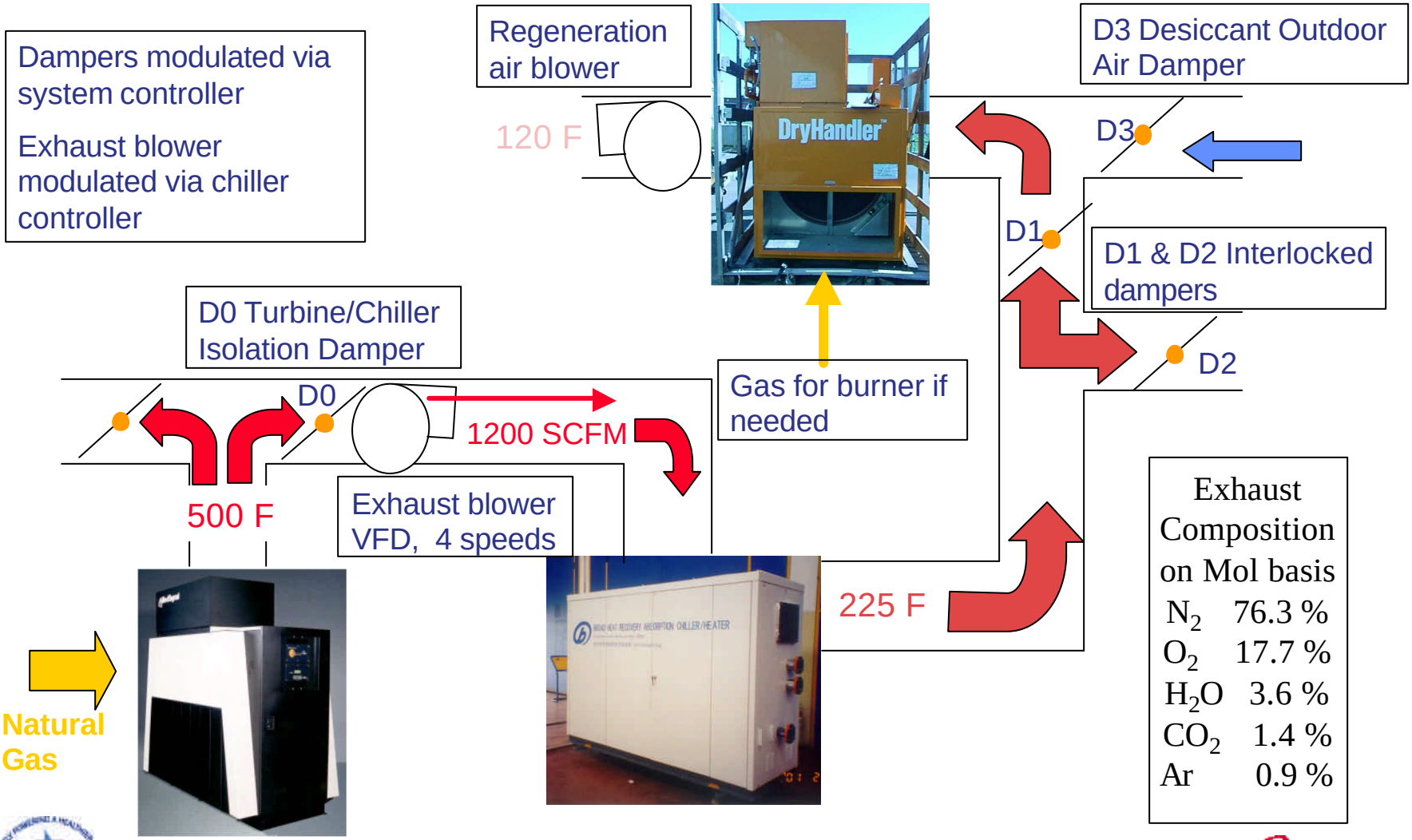
CHP System 2



- Turbine efficiency 25.6 %, with chiller 63.5 %, and with desiccant 79.2%
- Single effect absorption chiller with COP of 0.7
- Supplemental cooling provided by existing RTU

System 2 Heat Recovery



Exhaust Composition on Mol basis

N_2	76.3 %
O_2	17.7 %
H_2O	3.6 %
CO_2	1.4 %
Ar	0.9 %

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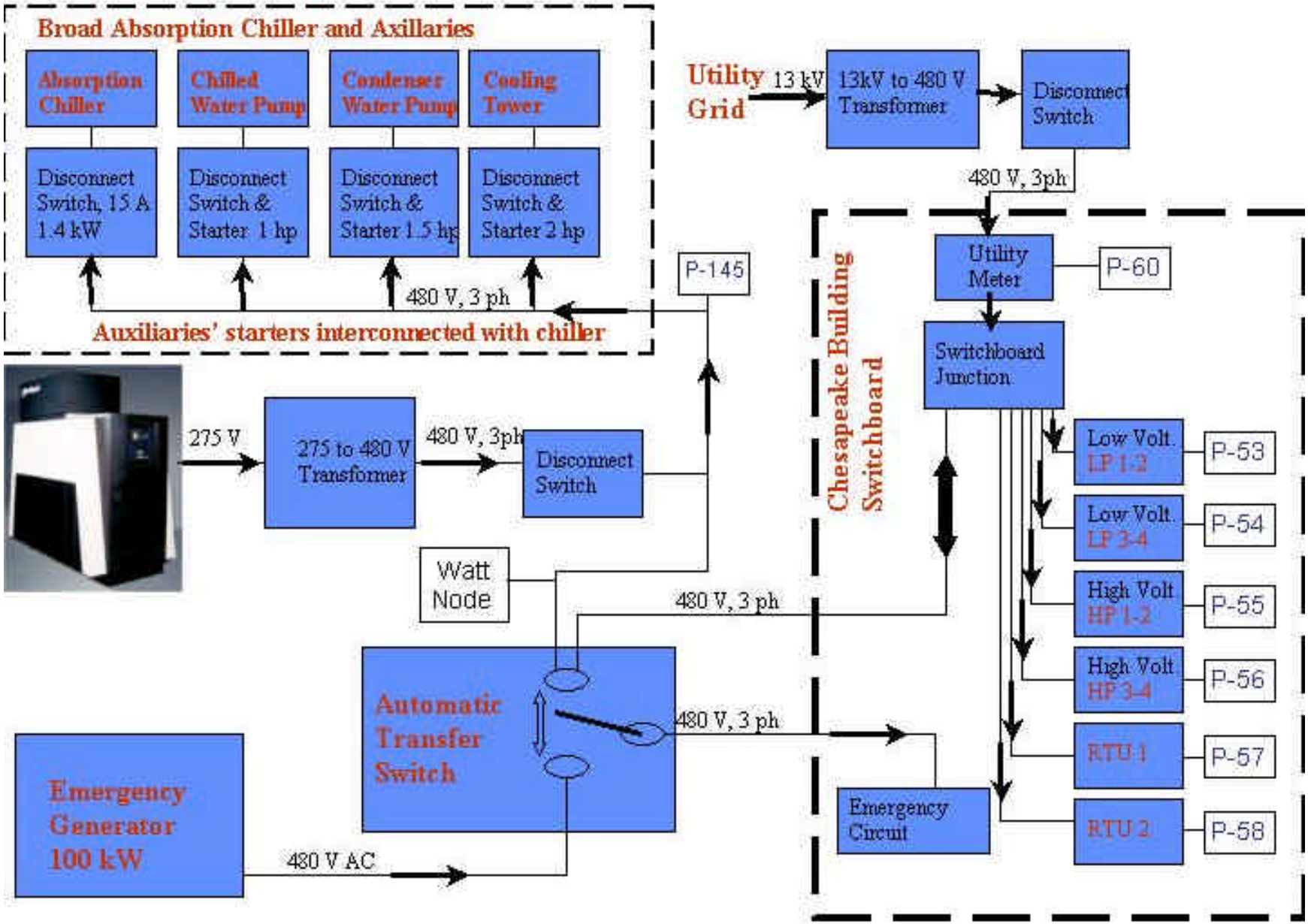
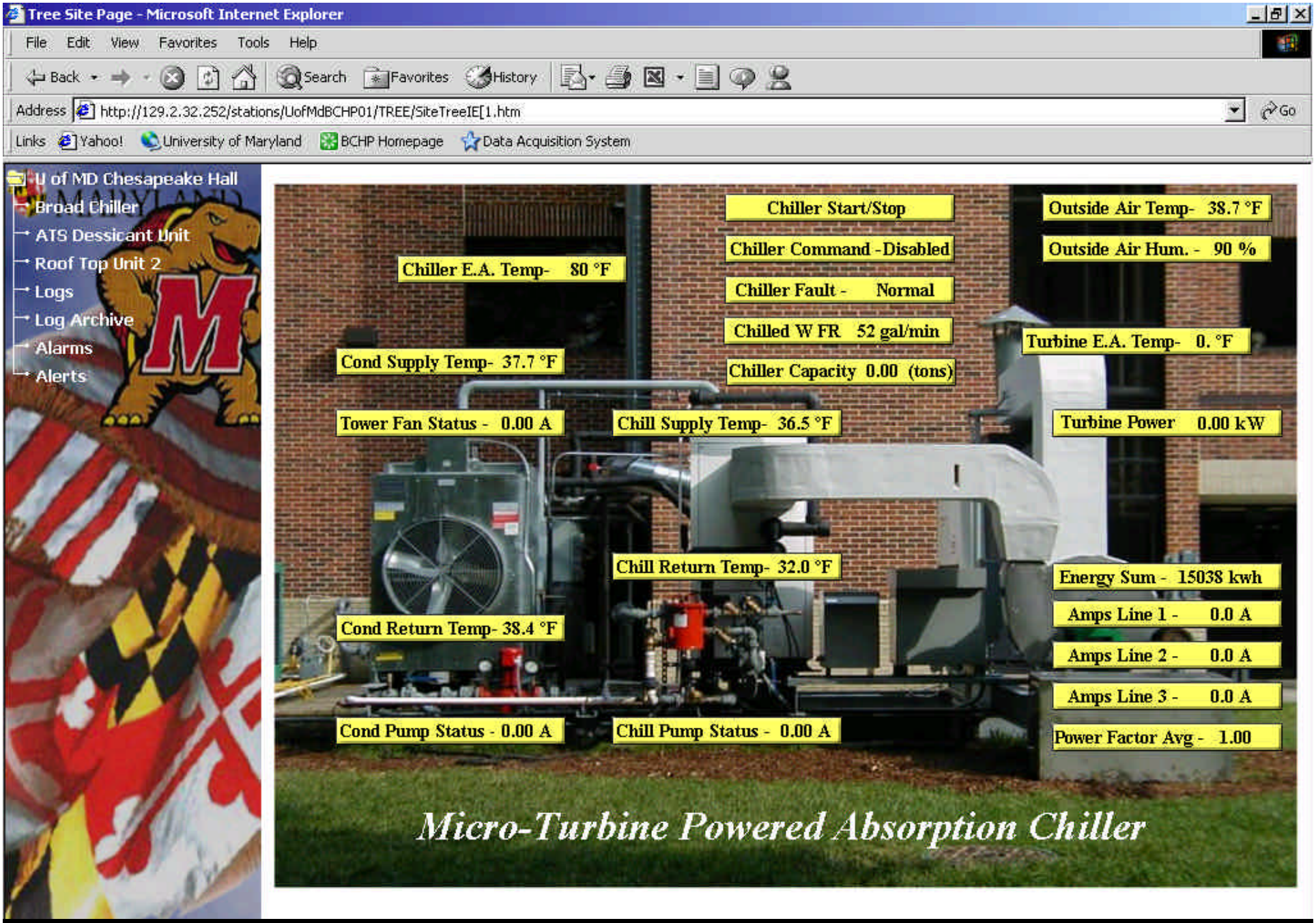
CHP System 2 Electric



BROAD HEAT RECOVERY ABSORPTION CHILL



www.enme.umd.edu/ceee/bchp

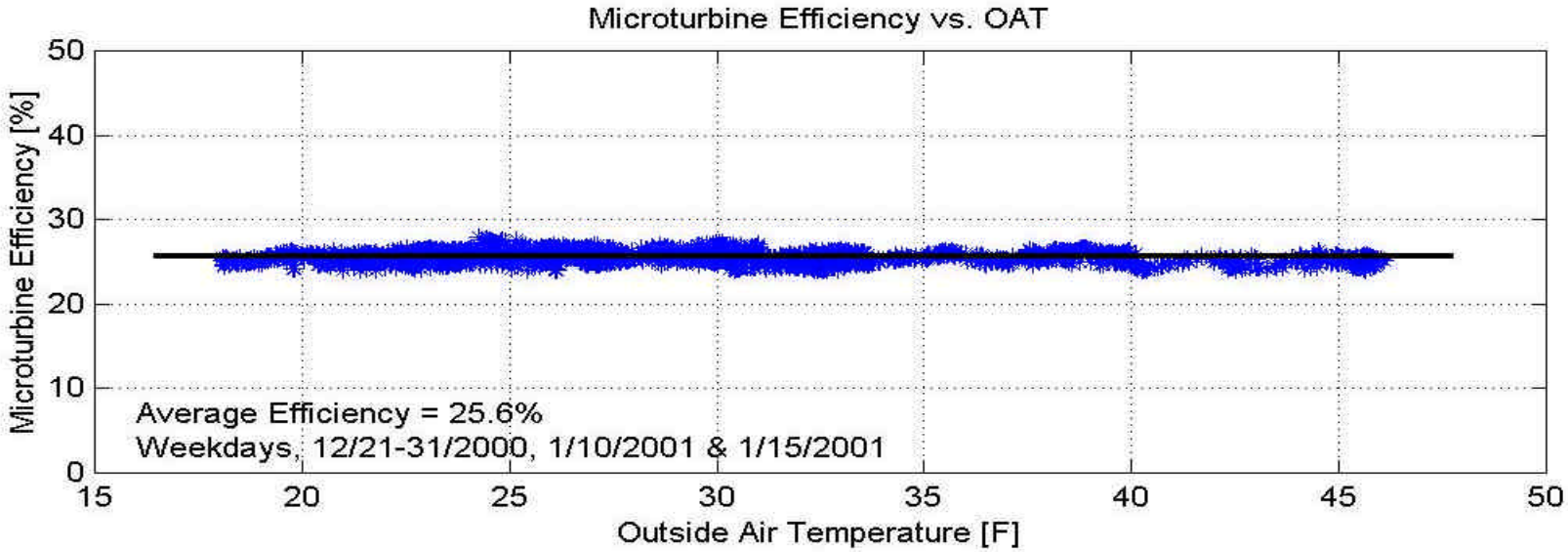
Honeywell Parallon 75 Microturbine

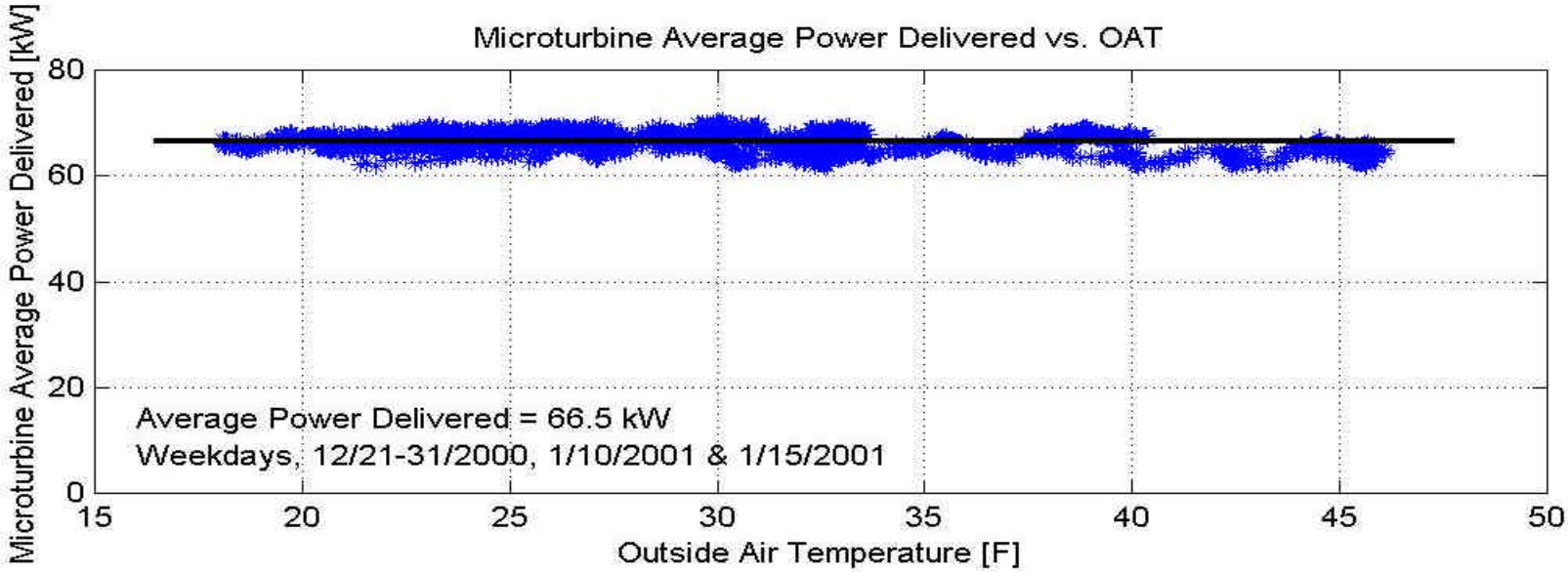
- Ran for 1500 hours
- Electric efficiency at the rated capacity 25 %, listed at near 29%
- Efficiency reduced due to losses in transformer and gas booster compressor
- Efficiency drops at part load conditions
- Start up sequence takes 4 to 6 minutes
- Repeated emission testing showed expected rates of pollutant emission (SRI Report)

Honeywell Parallon 75 Microturbine

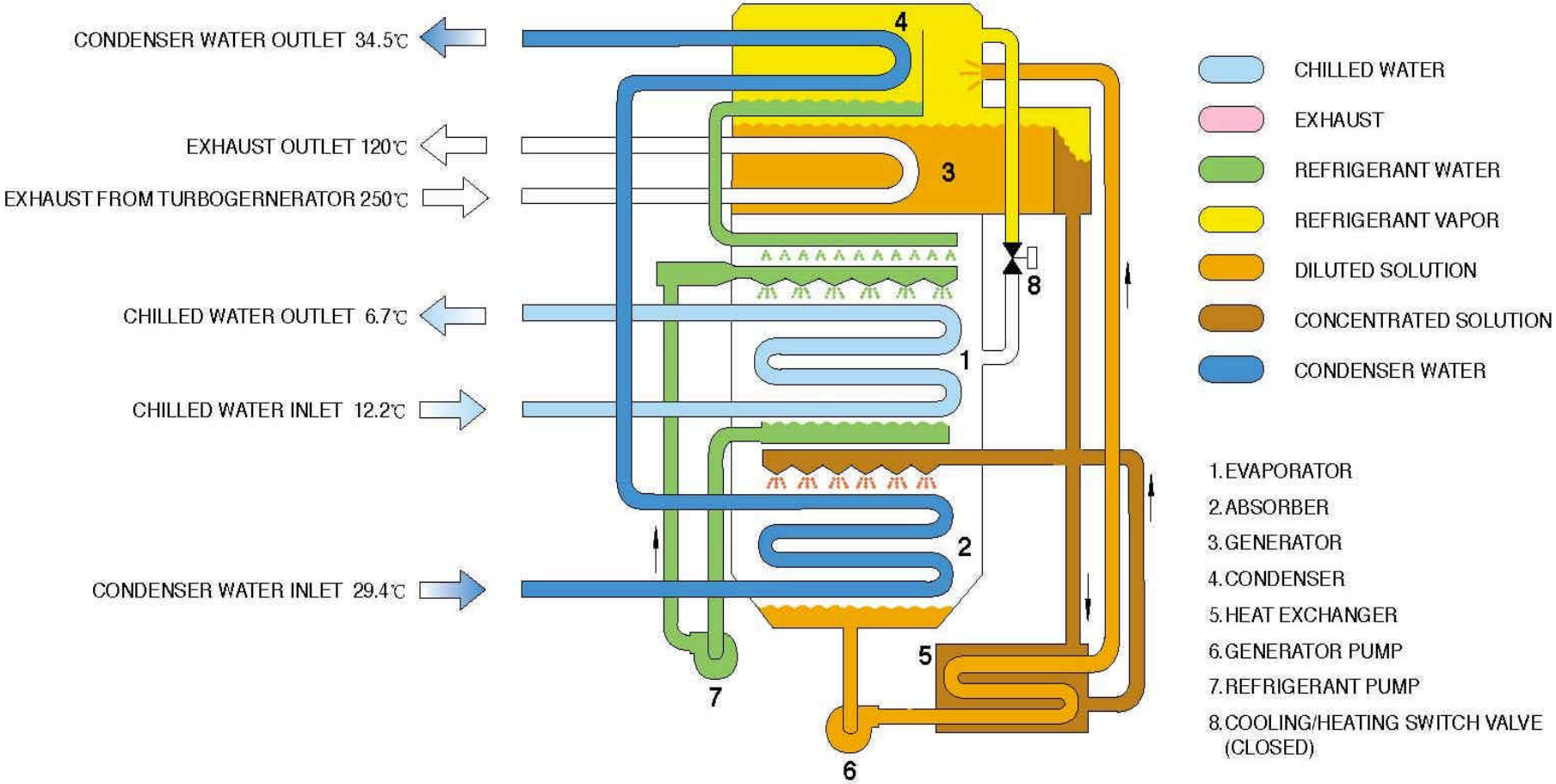
- CO emissions found high at part load conditions
- Catalyst coated recuperator installed,
  - Eliminated high CO emissions, but reduced efficiency
  - Electric efficiency dropped about 2 percent, with higher than rated exhaust temperatures
- 2 engine cores replaced, one due to air bearing failure other due to a ruptured seal in the core
- No effective communication provided between turbine's controller and the automation system
- Power and gas meters installed to monitor microturbine performance
- Microturbine software capable of logging some internal performance parameters

Microturbine Performance

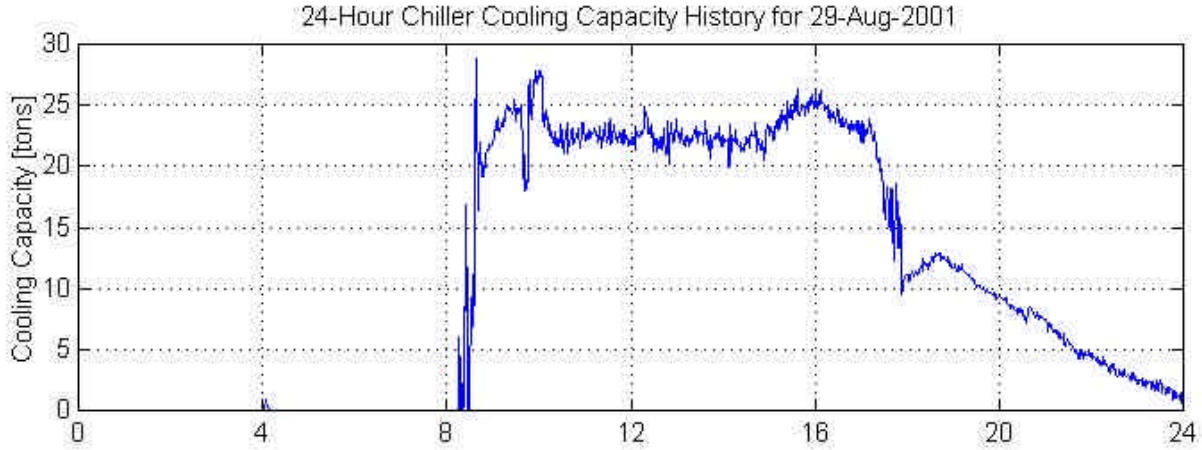


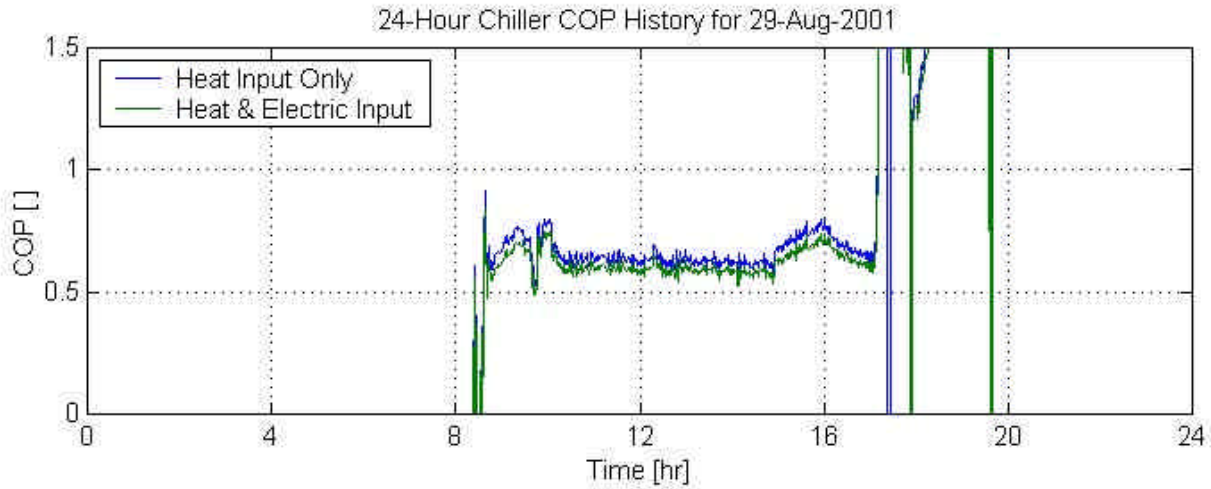


2ND CHP SYSTEM Absorption Chiller

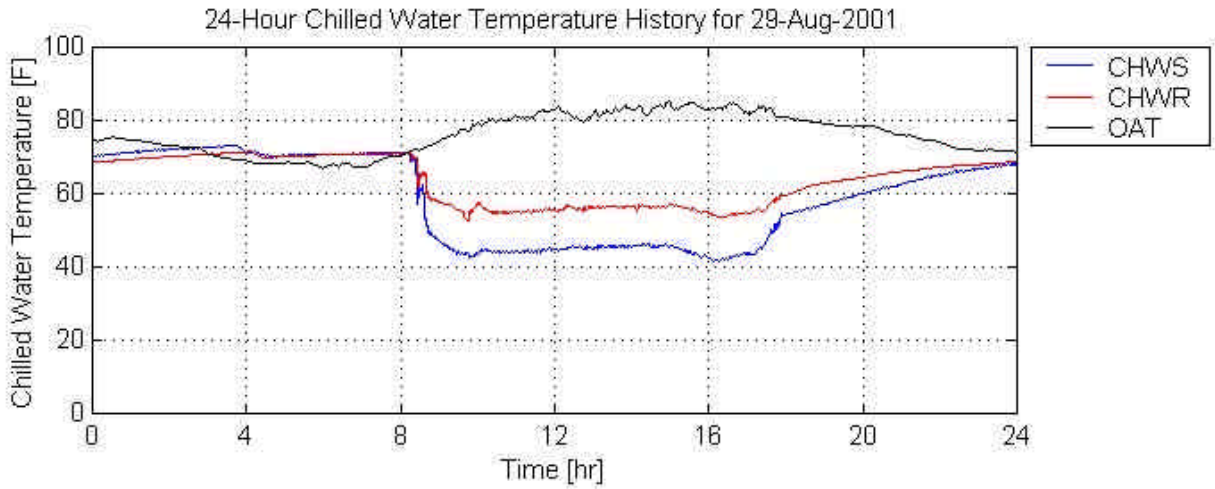


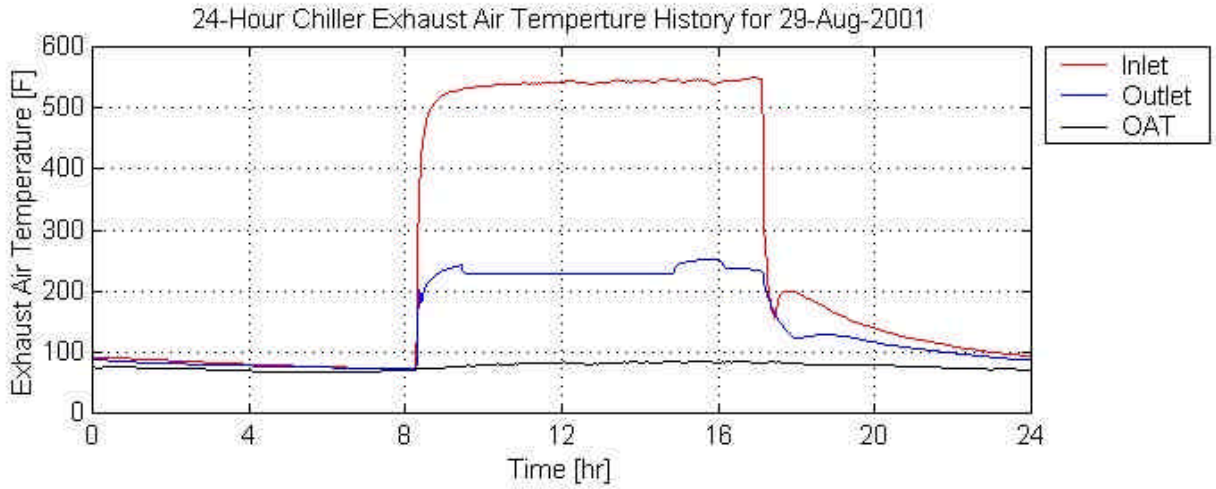
Absorption Chiller Data





Absorption Chiller Data





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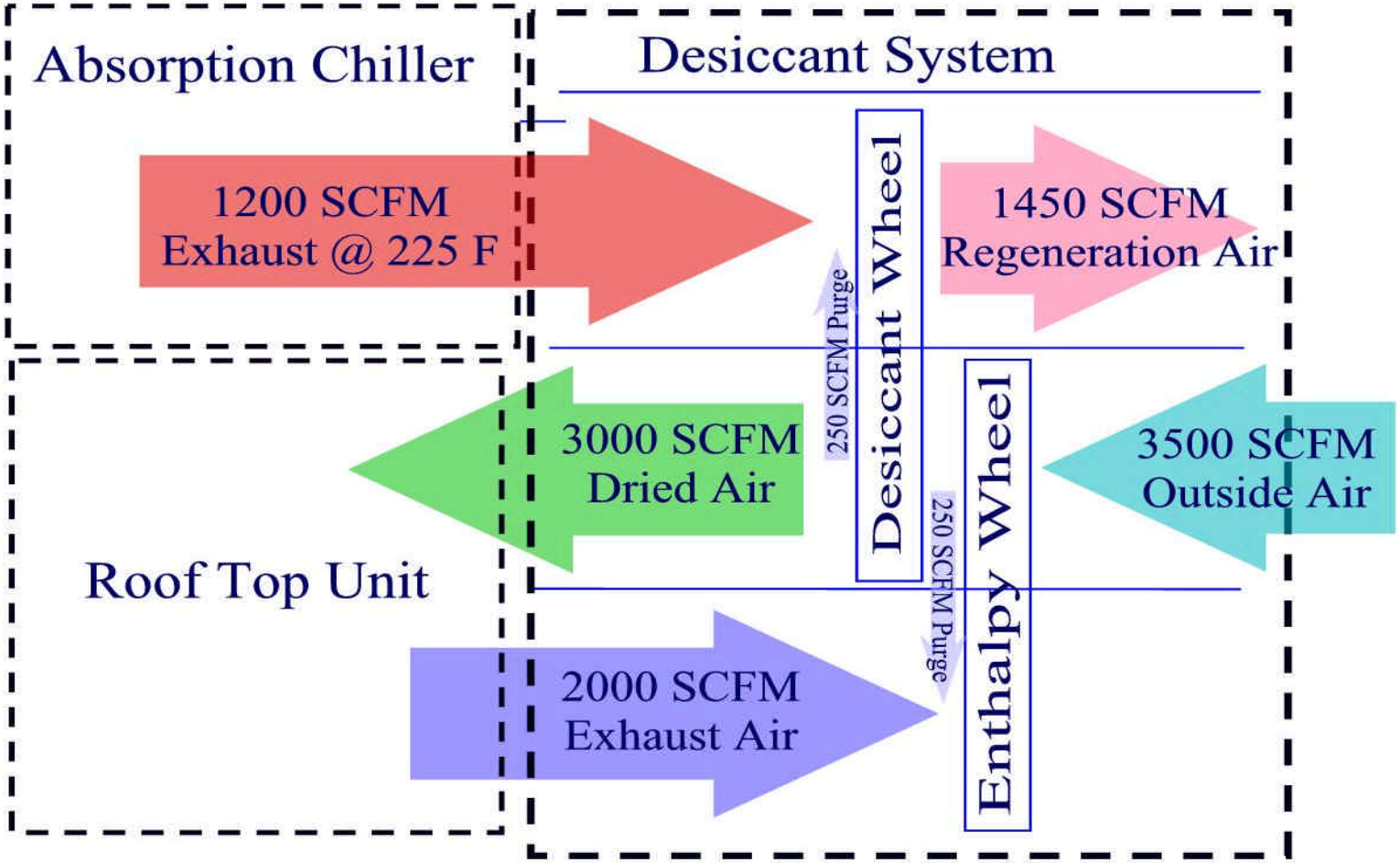
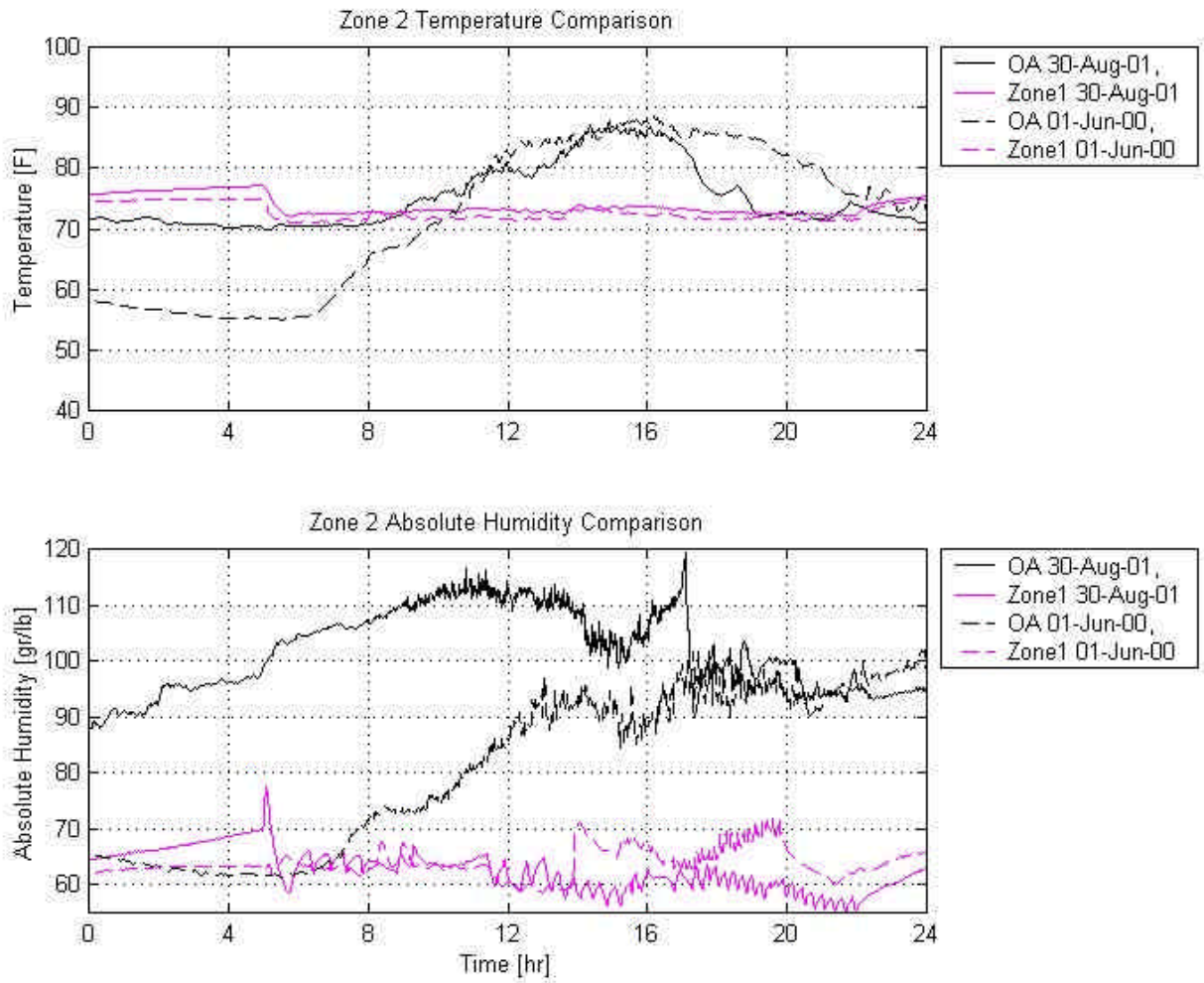
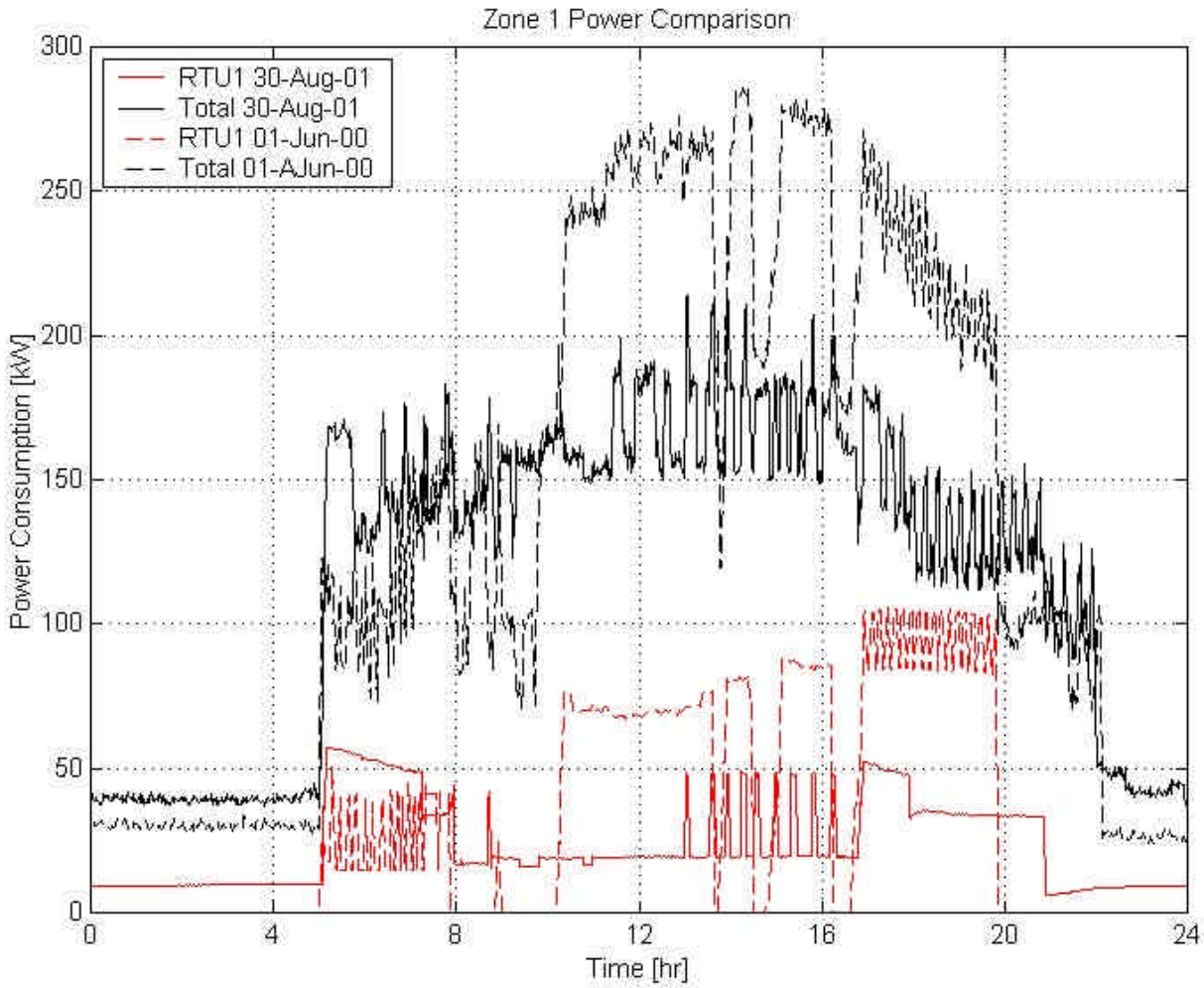
2ND CHP SYSTEM Desiccant System



Combined Effects



Comparison



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Lessons Learned

- System integrator needed
- Packaged combined units
  - Cheaper installation
  - Smaller footprint
  - Higher reliability
- Maintenance more demanding & more complex than for conventional HVAC equipment
- Turn key installation necessary including extended service agreements

Lessons Learned

- Develop an integrated open controller
- Controls integration needed
  - Single controller cheaper
  - Equipment/controls manufacturers not necessarily supportive
  - Important operating control points buried in the self-contained controller
  - Open communication essential for integration
- Reliability can to be improved via advanced controls, advanced monitoring & diagnosticians

Lessons Learned

- Turbine Chiller Integration
  - Reduce power generation from parasitic loads
  - Turbine chiller isolation necessary
  - Recuperator design affects performance
- Engines/Heat Recovery
  - Waste heat recovery loop can be improved
  - Small heat exchangers cannot eliminate radiators
  - Exhaust heat exchangers part of engines

Lessons Learned

- Noise at acceptable limit, not louder than RTU
- Building occupants involved in project
  - Humidity control increases comfort
  - Dry space leads to increase in thermostat set point
  - Comfortable environment
  - IAQ assessment scheduled

Future Work

- Perform extensive data analysis, economic analysis
- Improve combined system performance
- Complete automation system using advanced controls
- Develop web monitoring tool
- Install diagnostician modules for system optimization
- Make use of energy storage
- Assess effect of desiccants in buildings and interaction with HVAC systems
- Expand project with new equipment and/or new building
- Equipment options for 2003?