A Case for CHP Commissioning

Combined Heat and Power (CHP) for Commercial Buildings: Best Practices and Pitfalls

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Acknowledgements

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Case Studies

- *a San Francisco hotel retrofitted with a “packaged” microturbine generator/double-effect chiller plant*
- *a Los Angeles casino retrofitted with an advanced reciprocating engine, hot water heat recovery and a single-effect absorption chiller*
- *a Brooklyn laundry retrofitted with two reciprocating engine generators and a hot water heat recovery system*
- *a state-of-the-art hospital in Austin, TX with a combustion turbine, heat recovery steam generator, absorption and electric chillers and thermal storage.*

Note

CHP systems are more complex involving increased attention to atmospheric emissions and electric grid interconnection and sophisticated control logic.

CHP Elements to Consider

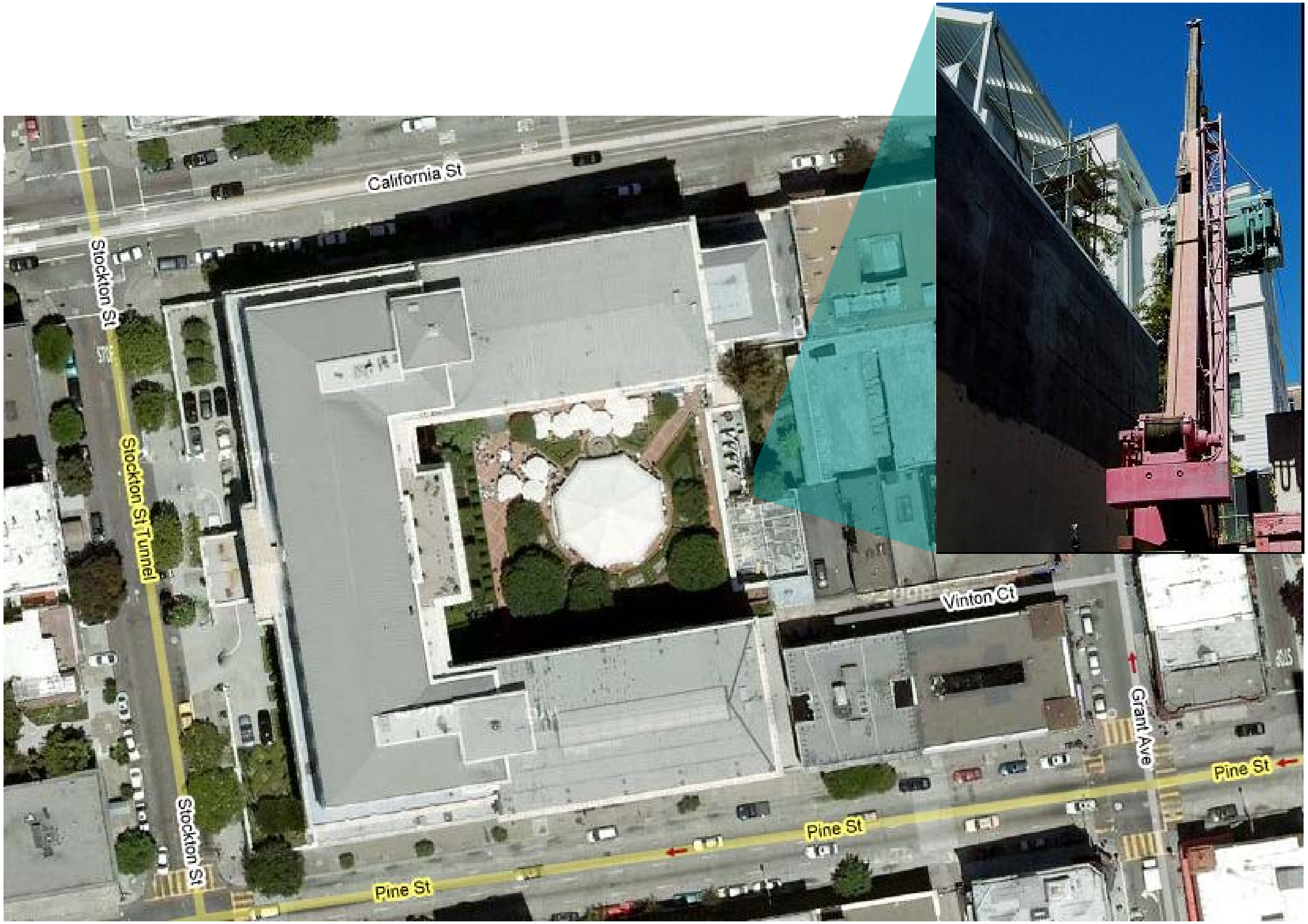
- Continuous duty drivers
- Emissions
- Generators
- Interconnection
- Waste heat recovery schemes
- Thermal technologies
- CHP integration
- Building system integration

COMMISSIONING A MICROTURBINE/CHILLER CHP PLANT AT A SAN FRANCISCO HOTEL

The Ritz Carlton

The Ritz Carlton

The Ritz Carlton



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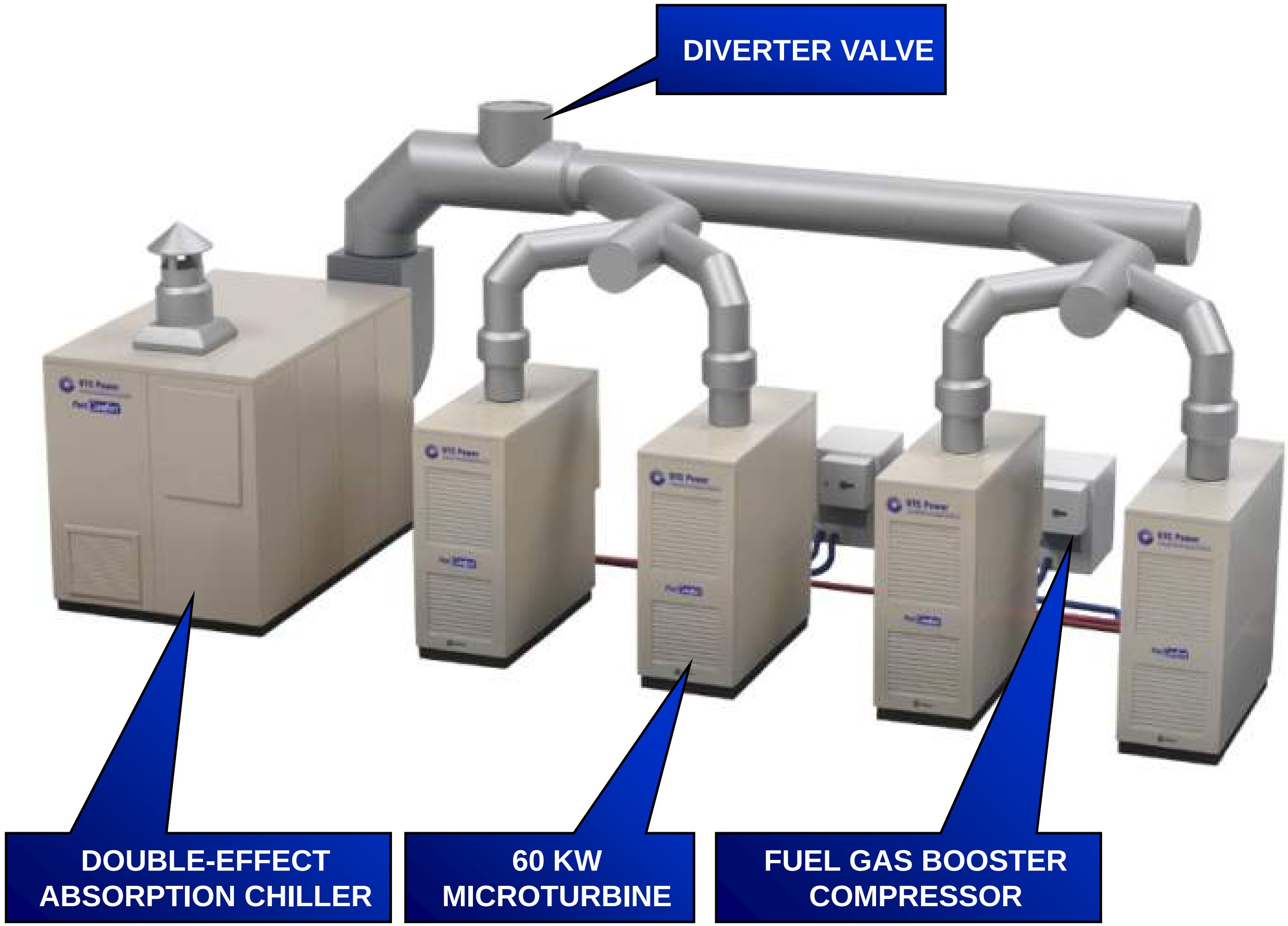
The CHP Plant

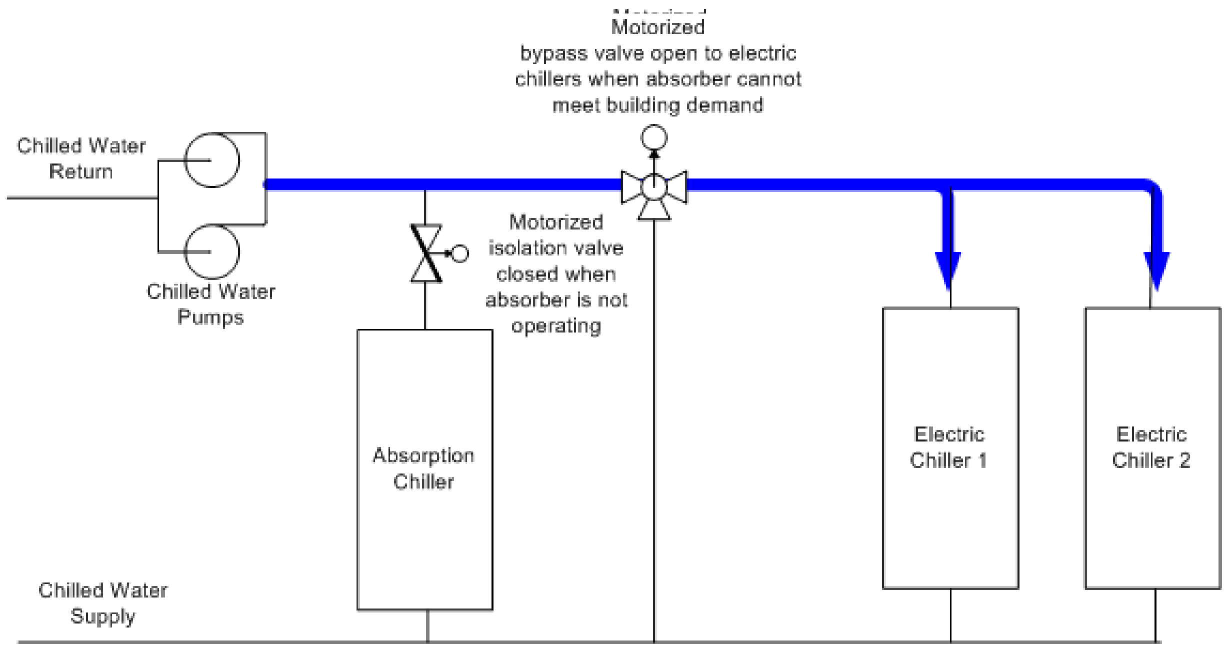
Microturbine/Chiller CHP



Design Performance

Rated Performance at 95ºF (35ºC)		
Net Power	kW	193
Cooling	RT	124
CHP Efficiency	%	80
Rated Performance at 59ºF (15ºC)		
Net Power	kW	227
Cooling	RT	142
CHP Efficiency	%	91

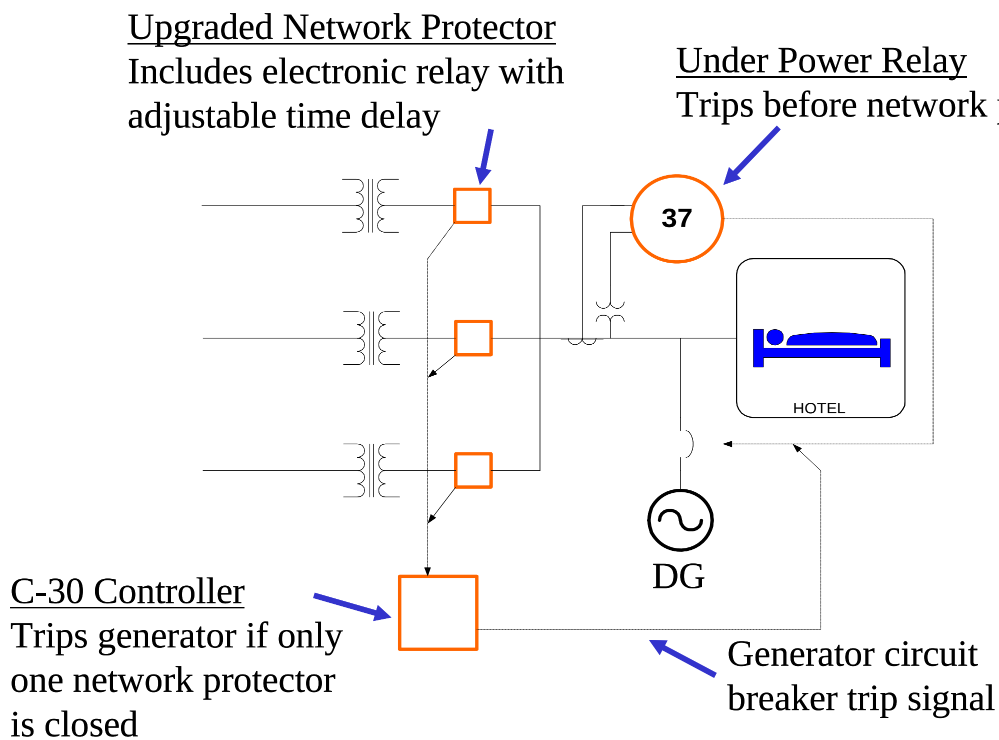
Thermal Integration



Electric Chiller Mode

Grid Interconnection

The hotel connects to PG&E's San Francisco "network" through multiple feeders to the site.



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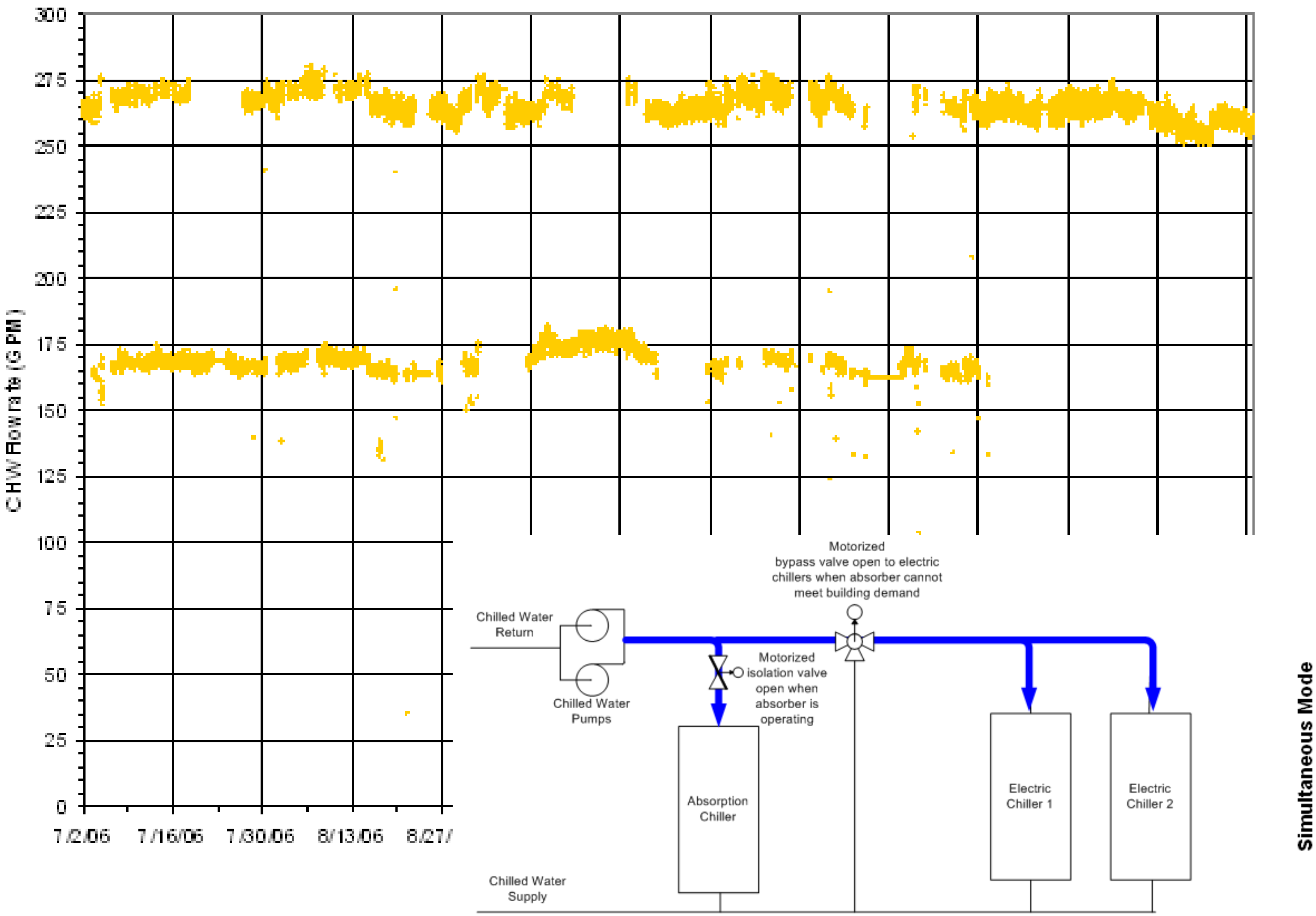
Commissioning

- **Commissioning of the CHP system was completed by Carrier under contract to UTC Power.**
- **The commissioning was performed according to a written protocol that provided guidelines for startup of both the microturbines and the absorption chiller.**
- **The effectiveness of the grid protection circuitry was confirmed.**
- **The microturbines were started and performance was verified.**
- **The chiller was evacuated of the nitrogen blanket that had been applied for shipping. The chiller was then started and the charge level was verified.**
- **Once commissioning was completed the system was put into service.**
- **It should be noted that there was not a formal report generated with respected to the exact extent of the commissioning process.**

Commissioning

- **Overall, the CHP System achieved an extremely high level of utility with minimal outages. The CHP System producing at least 60 kW of net electrical power for 8,231 hours, or 94% of the year.**

Absorption Chiller Flow



Observations

- The commissioning process took place in the winter precluding interaction between the CHP absorption chiller and the hotel's existing electric chillers.
- The anticipated chilling level was based on both predictions it was not as easy to determine thermal loads. Perhaps this design flaw suggests the need for a new assessment approach to measuring thermal system performance prior to building retrofits.
- The second design flaw stems from the integration of the absorption chiller into the existing chilled water circuit which led to a 100 gpm absorption chilled water drop when the electric chillers were engaged.

COMMISSIONING A RECIPROCATING ENGINE/CHILLER CHP PLANT AT A GARDENA, CA CASINO

Normandie Casino

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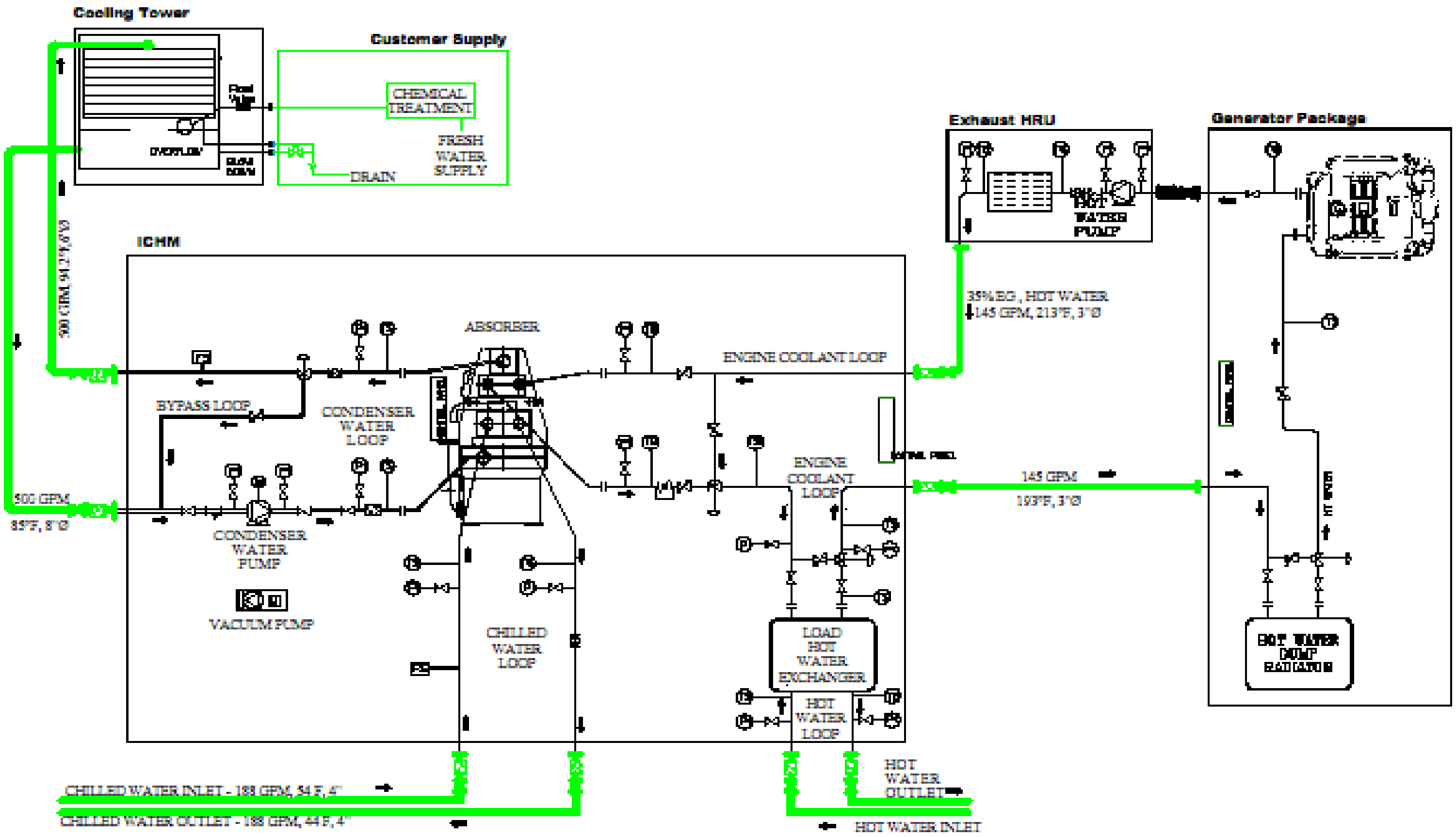
CHP Plant

CHP Plant

CHP Plant

- **Electricity is supplied from the local electric utility. Existing chillers include a 4-compressor 80 ton reciprocating chiller and a 120 ton centrifugal chiller. Space heating needs are minimal and domestic hot water is provided by two boilers with integrated storage tank.**
- **CHP System Design**
  - *255 kW generator module*
  - *Gas Heat Recovery Module*
  - *Thermal System Module with a 75 ton chiller*
  - *Cooling Tower*
  - *Engine Dump Heat Exchanger*

CHP Plant



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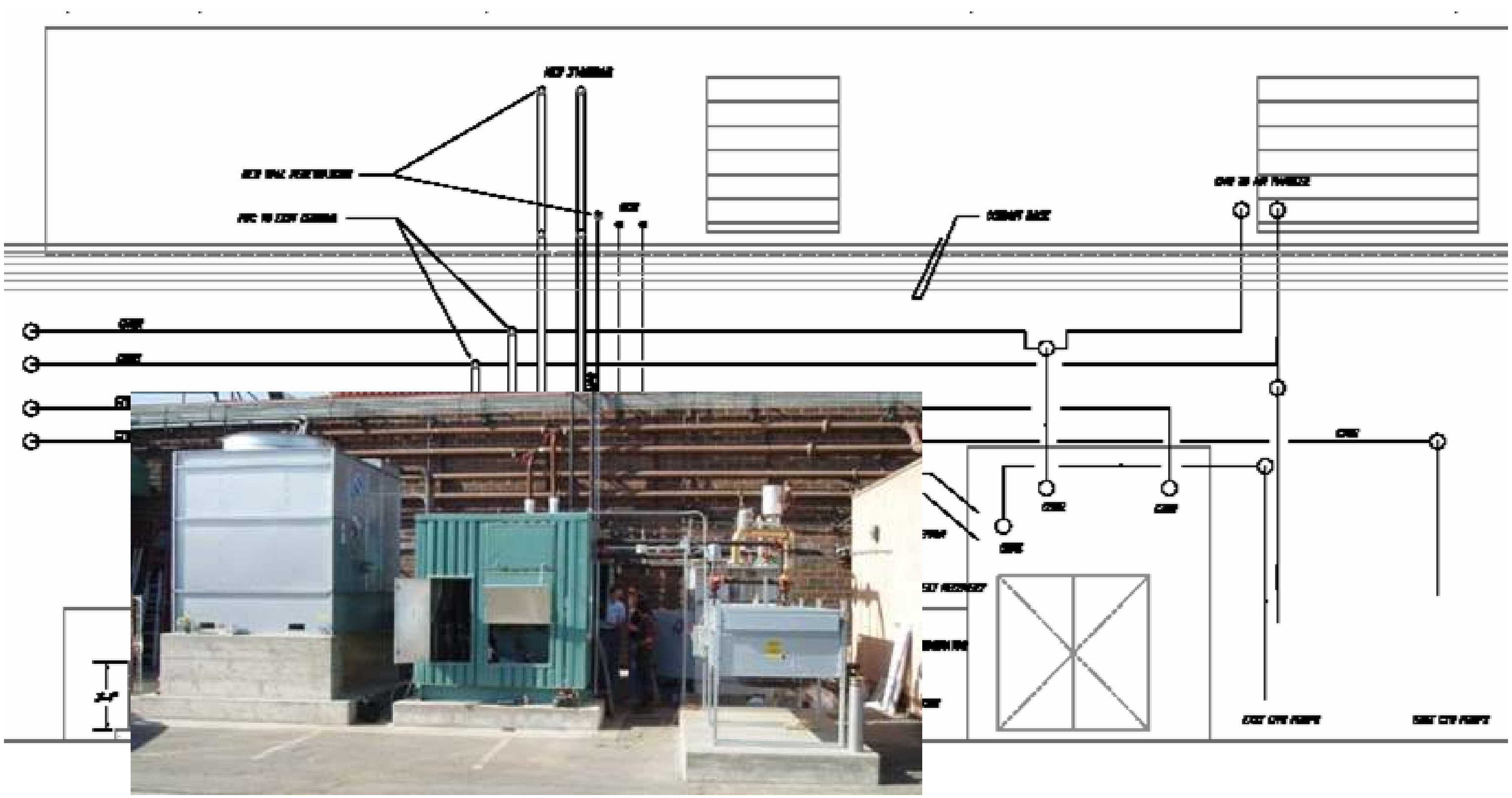
Building Integration



Building Integration Installation

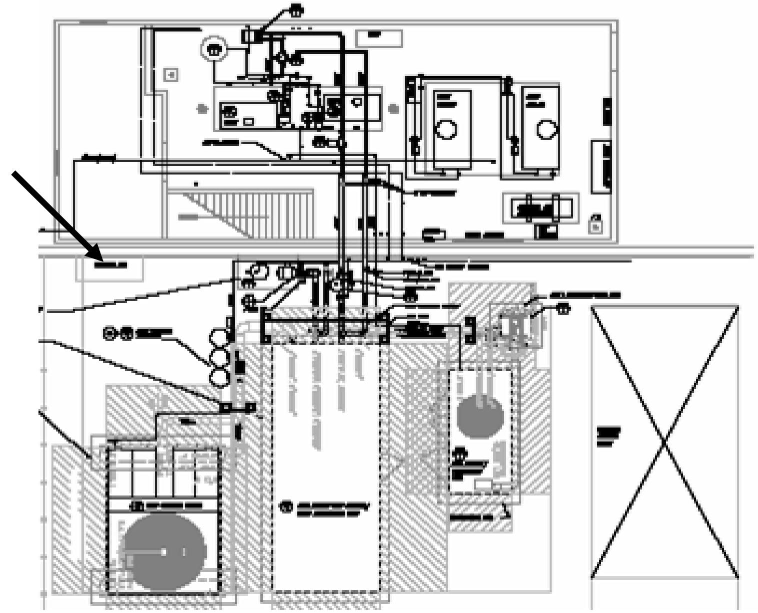
(Recip Chillers in adjacent room)

Chilled Water Header

Chilled Water Tie-in

Dom HW Heaters

Space Heaters



Cooling Tower

Chiller Module

Engine Generator

Centrifugal Chiller Room

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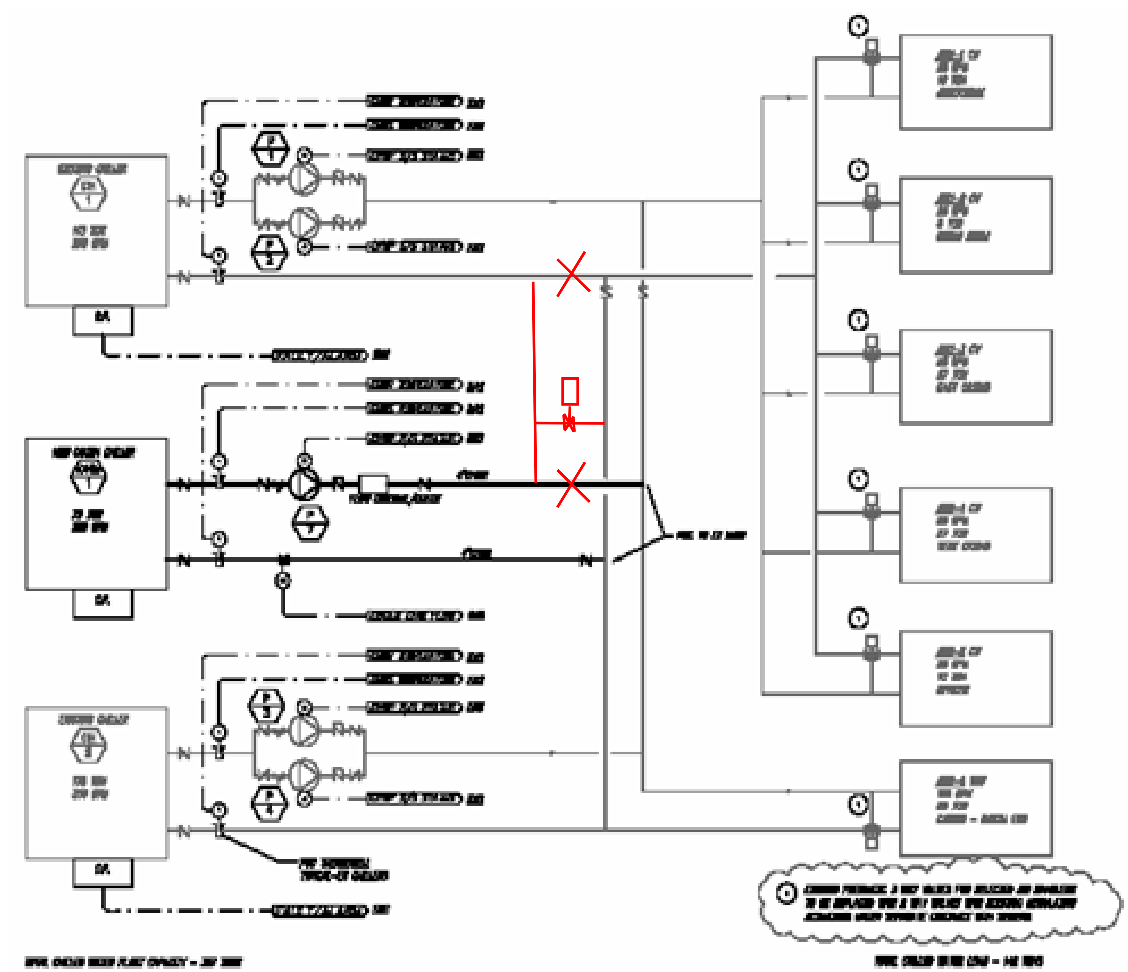
Chilled Water Piping

- The CHP chiller was tied into a common header with the existing two chillers and each chiller had its own pump feeding 6 AHU’s
- Flow balancing problems were immense and the design provided no way to baseload the thermal chiller.
- Note that the three way valves supplying the six air handlers had been replaced with two way valves eliminating the ability to bypass causing low flow alarms on both the reciprocating compressor chiller and absorber.

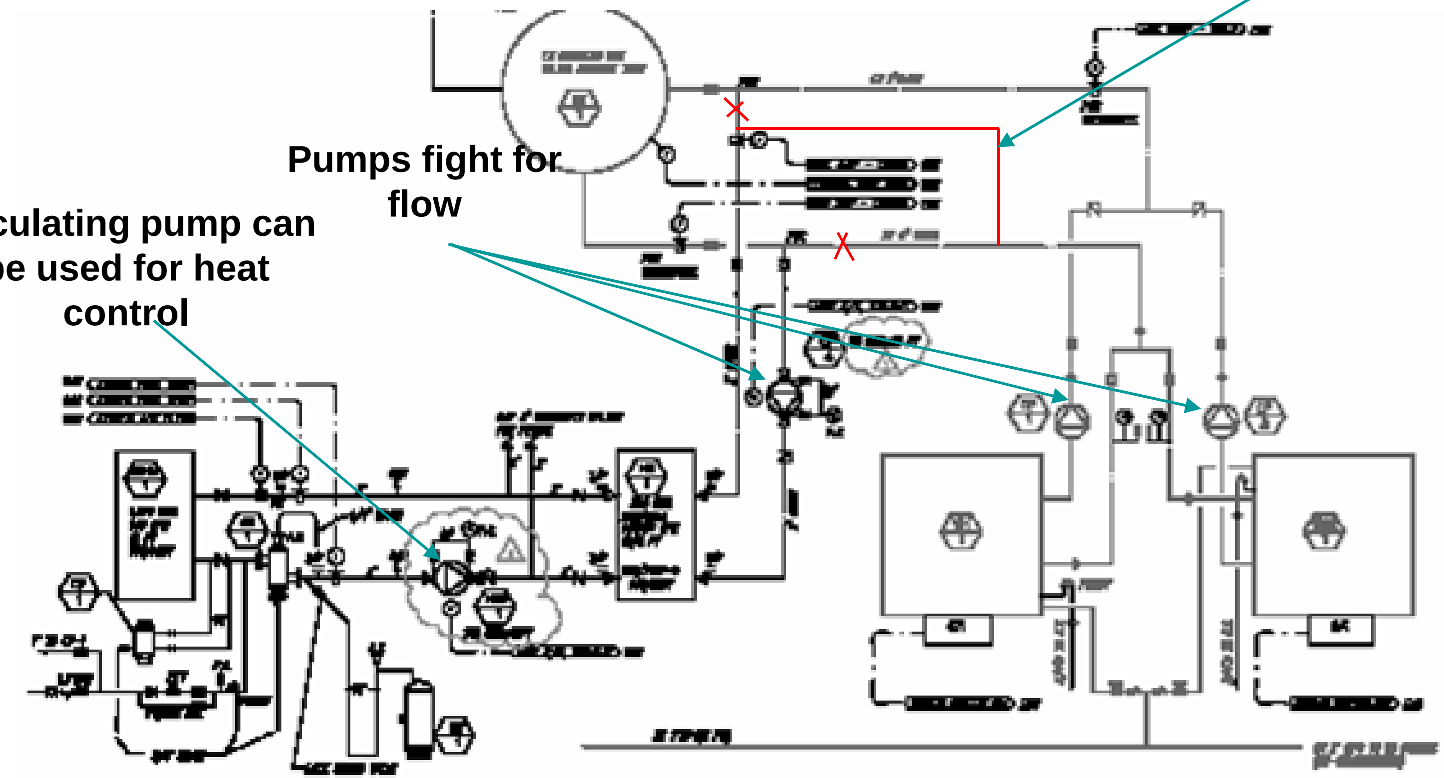
Recommended Changes

3 chillers tied into header with individual pumps. Flow balancing problems and no way to baseload chiller. Series piping and pump modifications would correct.



Installation Issues

While parallel piping allows CHP to be turned on or off, it causes conflict with existing boiler pumps and prevents baseloading.



Installation Issues

Do remove packing caps and flush lines

Installation Issues

- Set PRV's and charge expansion tanks
- Include filters on pumps

Field Test

- Thermal Module was run by itself with the electric chillers manually locked out.
- The engine generator was ramped up to 260 kW and the engine jacket return temperature was increased to 195 F.
- Data was taken after the system stabilized and showed the chiller was holding the load at between 60 to 70 tons during three hours and the chilled water supply temperature remained at set point showing the system was not overloaded. The Thermal Module chiller load peaked at 72 tons at 2:12 PM. However, there was no more load available and after 4 PM ambient conditions further reduced the load. The chiller held set point throughout the remainder of the day.

Observations

- Factory test proved performance
- Site test at commissioning did not allow for full load but did prove system operation.
- Weather during commissioning is a large factor in generating heating or cooling load.
- Site engineering is a vital ingredient particularly for retrofit CHP installations “as built” drawings of complete building systems are often inaccurate or incomplete.
- Series flow should be used on all CHP thermal loops to balance flow and eliminate pumping problems especially in retrofit situations.
- Miscellaneous problems: packing caps not removed from piping, field lines not flushed, pressure reducing valves not set, expansion tanks not charged and filters not included on pumps.

COMMISSIONING A RECIPROCATING ENGINE/WATER HEATING CHP PLANT AT A BROOKLYN, NY LAUNDRY

Arrow Linen


ARROW LI
467 PROSPECT A
Windsor Pl
Prospect Ave
Prospect Park West
17th St

CHP Plant

- Comprised of two reciprocating engine packages with a maximum aggregated output of 300 kW.
- The system was sized to meet the average electrical load for the plant.
- The system recovers waste energy from the engines' cooling water and hot exhaust to supply most of the hot water needs at plant.
- The system has operated exceptionally well since its installation, supplying 70% of the plant's power needs and 14% of its thermal needs with an overall efficiency of 76%.

CHP Plant

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CHP Plant

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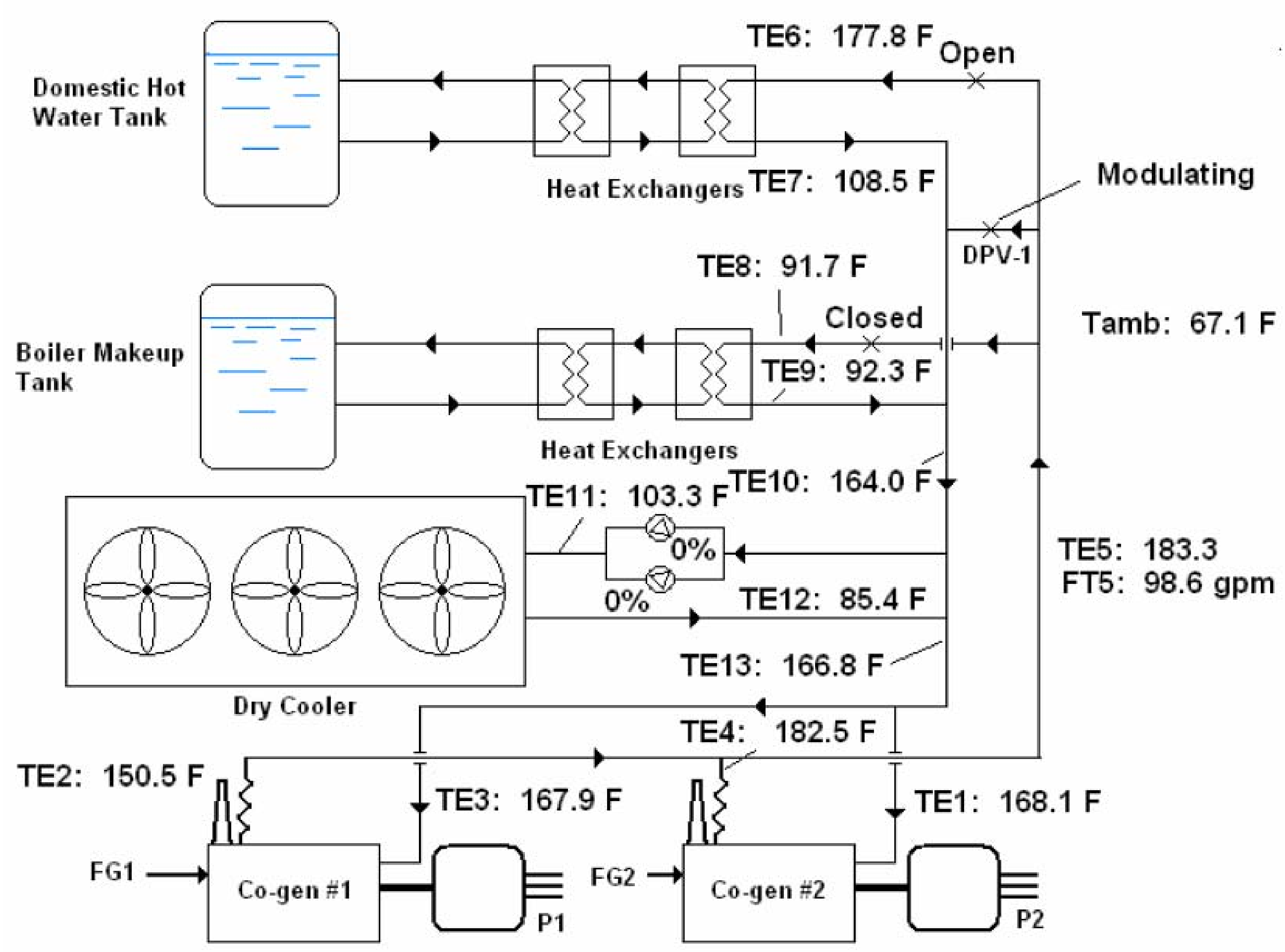
Building Integration



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GRID Interconnection

- There were many parties required to witness the test interconnection test.
- Changing the test methods made it very difficult to carry out the test.
- The utility engineer also had an issue with the type of utility disconnect switch used and the location where the switch was installed. The switch was a circuit breaker type instead of a knife type with fuses and the switch was not installed in the basement as specified in the Inter-connect manual.

Power Control Issues

- The original ALC consisted of a Programmable Logic Controller (PLC) to send analog signals to the individual generator control to vary kW output to maintain a set importing kW from the utility.
- When there was a sudden drop in a facility's electrical load and the generator could not react fast enough thus causing the Inter-tie Breaker to open on Reverse Power.
- The problem was resolved by replacing the PLC with a wattmeter to retransmit an actual importing kW to a generator control. As the importing kW from the utility got closer to the set point, kW output from the generators defaulted to a minimum output instead of trying to maintain a set importing kW.
- This caused an increase in electrical demand from the utility. If the utility did not require the reverse power relay and the generator's ramping capability was faster, then, this would not have been an issue

Other Issues

- The generators shut down on Voltage and Frequency faults. The generators were out of commission until the root cause of the problem was determined. The cause of the problem was due to a faulty feeder cable to Generator #2. The feeder cable insulation failed due to a vibration thus causing a shifting of voltage and frequency.
- The dump heat exchanger was short cycling and available heat generated by the generators was not being utilized.
- Water flow through the heat exchangers was not balanced and the balancing valves were not installed.
- When the return water temperature to generators fell below the threshold point, the DDC controller would bypass the heat exchangers to prevent condensation from occurring inside the engines. This caused the heat exchanger valves to short cycle. To resolve this problem, a limit provision was added in the DDC's thermal recovery program taking into consideration the outside air temperature and the number of generators that are online de-rating the heat exchangers capacity accordingly to maximize heat recovery.

Observations

Some problems arose due to installation issues, climate changes and the equipment provided did not work as anticipated. It took some time to address all these problems and issues. A major attribution for delaying and addressing some of the problems was due to a fall out between the contractor/Generator Distributor and the Generator Manufacturer.

COMMISSIONING A GAS TURBINE/HYBRID CHILLER CHP PLANT AT AN AUSTIN, TX HOSPITAL

Dell Children's Hospital

The key design goals for this CHP plant were:

- **Maximum possible energy efficiency**
- **Significant reduction in emissions, especially carbon**
- **Improved reliability with grid independence option**
- **Investment grade financial returns**
- **Green building and become the first LEED® Platinum hospital**

CHP Plant Components

- Chiller water primary and secondary pump module
- Packaged duplex electrical centrifugal chiller plant totaling 1,500 refrigeration tons
- Packaged boilers totaling 22,000 lbs/hr of steam
- Thermal energy storage tank totaling 8000 ton-hours of chilled water
- 1,500 kW black start engine generator
- Fuel gas compressor module
- 4.3 MW combustion turbine
- Turbine exhaust diverter valve and stack
- Steam absorption chiller totaling 1,000 refrigeration tons
- Heat recovery steam generator (HRSG)
- HRSG Exhaust Stack

CHP Plant

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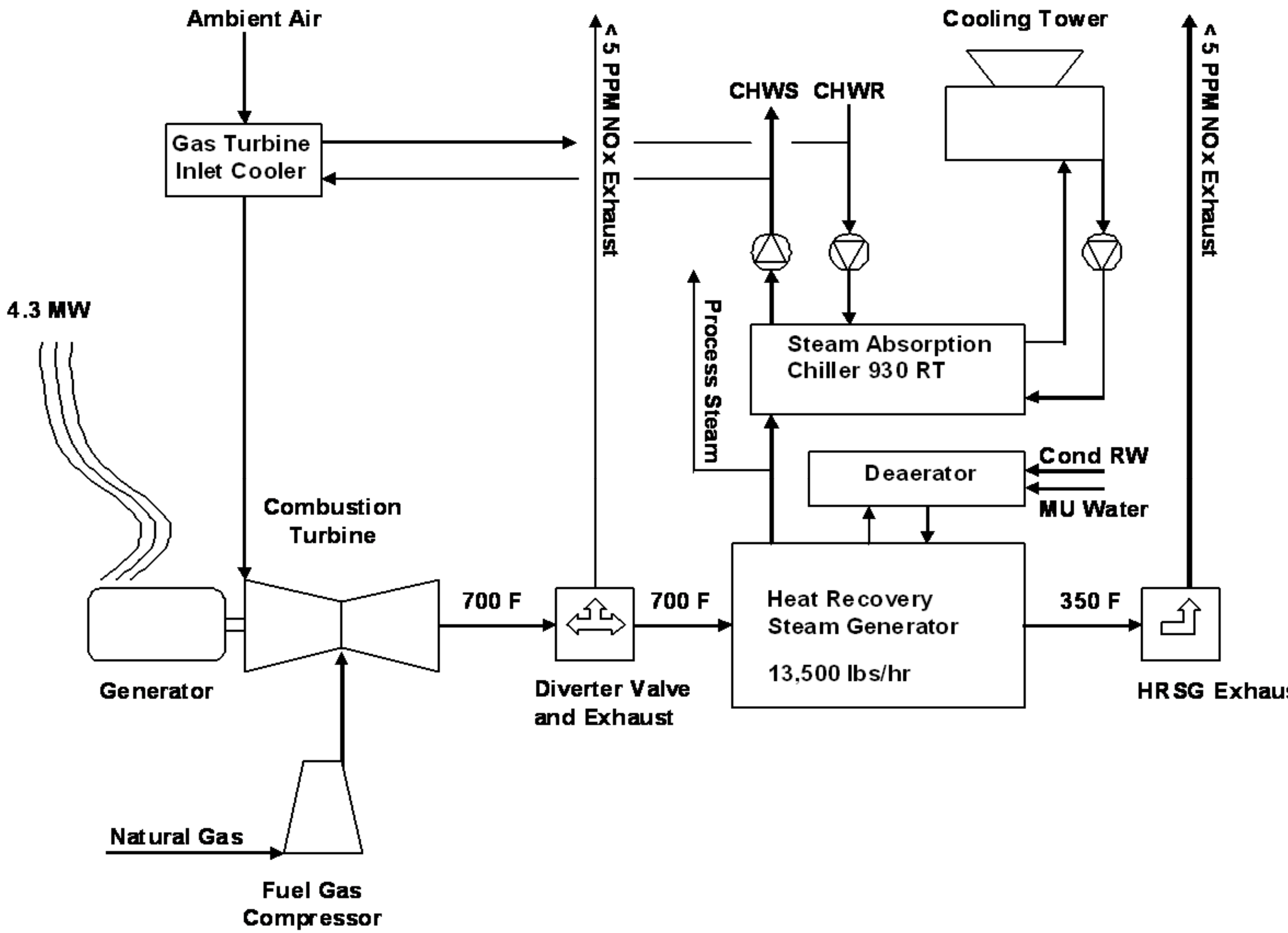
CHP Plant

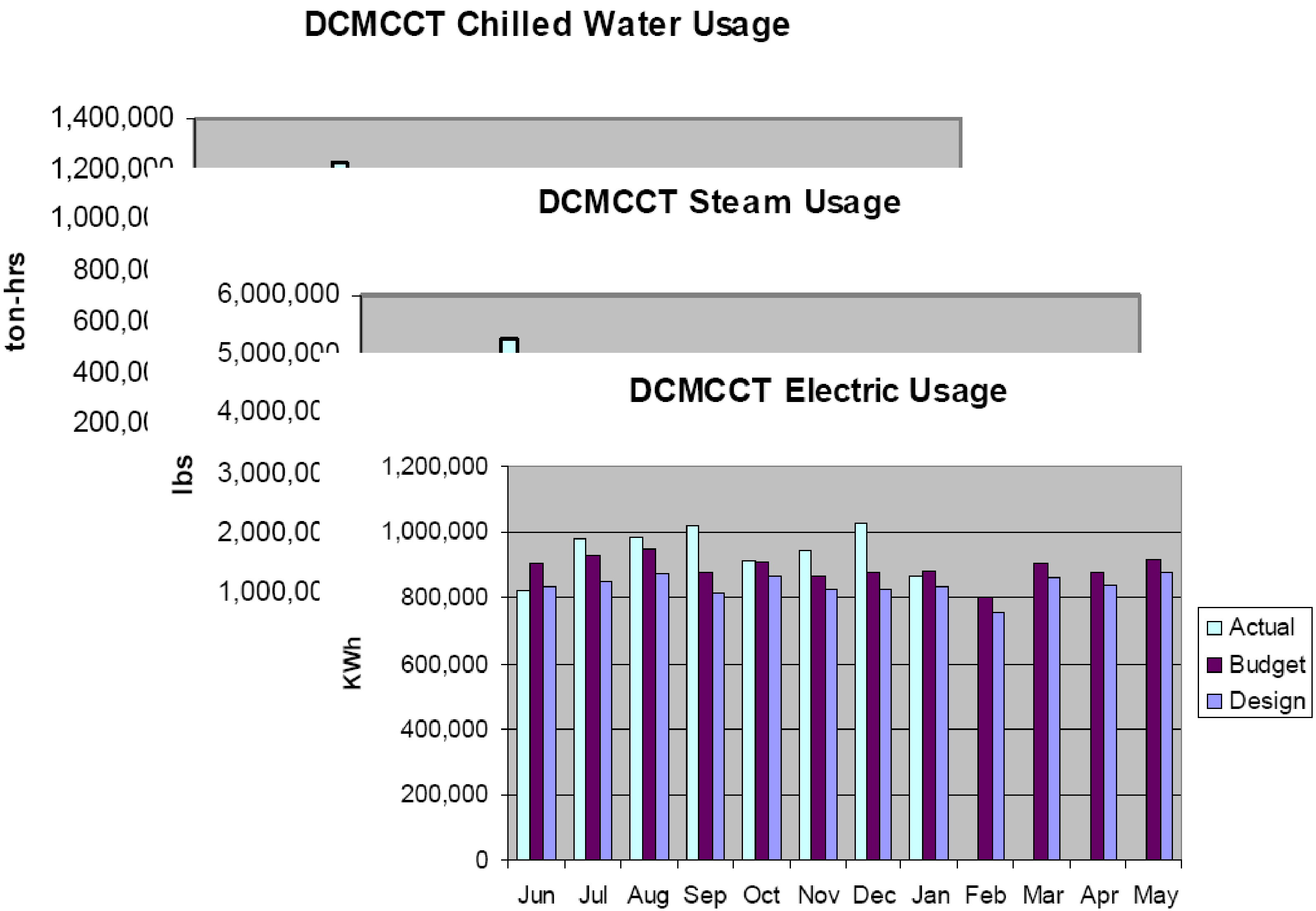


Ambient Air
Gas Turbine Inlet Cooler
< 5 PPM NOx Exhaust
CHWS
CHWR
Cooling Tower
< 5 PPM NOx Exhaust
4.3 MW
Process Steam
Steam Absorption Chiller 930 RT
Cond RW
Deaerator
MU Water
Combustion Turbine
700 F
700 F
Heat Recovery Steam Generator
13,500 lbs/hr
350 F
Generator
Diverter Valve and Exhaust
HRSG Exhaus
Natural Gas
Fuel Gas Compressor

Commissioning

- **The initial commissioning of the CHP hybrid plant was undertaken prior to June of 2007 by the contractor.**
- **In general, electrical power, chilled water and steam were effectively delivered to the Hospital within design parameters.**
- **The hospital building commissioning process was another story. The Hospital opened in June 2007 and was not fully commissioned at time of opening. Commissioning and recommissioning of HVAC equipment and controls and day lighting controls continued after opening until March 2008.**

The Hospital Load Profile



Observations

- An accurate 24/7 energy profile is needed for the CHP design. The profiles should be refined as the design process continues. At least four iterations should be considered: scoping study phase, feasibility phase, preliminary design phase, complete design phase.
- The HVAC/control system design must comprehensively be able to implement the energy control management strategies used for the energy modeling.
- Comprehensive submittal review is required to ensure control management strategies meet the design intent.
- If the schedule allows, complete all commissioning prior to occupancy.
- Post-commissioning after occupancy will result in greater energy savings as systems are tuned to the actual building operation.
- Tweak/adjust design after occupancy to optimize energy performance.

Observations

- Commissioning of the initial CHP installation was completed and plant operations was demonstrated under various scenarios.
- After installation of the initial plant design, and commencement of operations of the CHP, operations staff discovered that a failure of one transformer could render other plant systems unreliable. Therefore a new contractor was engaged to design and install the added transformer and switchgear to assure the N+1 reliability.
- A second electrical engineer and installation contractor for this new work came new risks associated with plant sequence of operations. The initial plant control sequence was modified to accommodate the new distribution equipment but in so doing, new points of failure were created.
- With a live CHP plant serving mission critical loads, subsequent commissioning is quite difficult and fraught with risks of inadvertent downtime.

Conclusions

Conclusions

- A written commissioning report is essential to determine exactly what was tested and how the tests were accomplished.
- All essential elements must be tested to assure functional performance.
- If timing and weather precludes performance testing of certain systems, arrangements should be made to perform these tests at a later date.
- Site engineering is a vital ingredient particularly for retrofit CHP installations because “as built” drawings of complete building systems are often inaccurate or incomplete.
- In retrofit situations series flow should be used on all CHP thermal loops to balance flow and eliminate pumping problems.
- Balancing valves are essential to assure flows are correct.

Recommendations

- Further Research
- Performance Protocols
- Commissioning Protocols
- Commissioning Database

Questions

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