Program to Develop Advances in Combined Heat and Power Systems

Subcontract NAD-0-30605-10
National Renewable Energy Laboratory

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Colorado School of Mines

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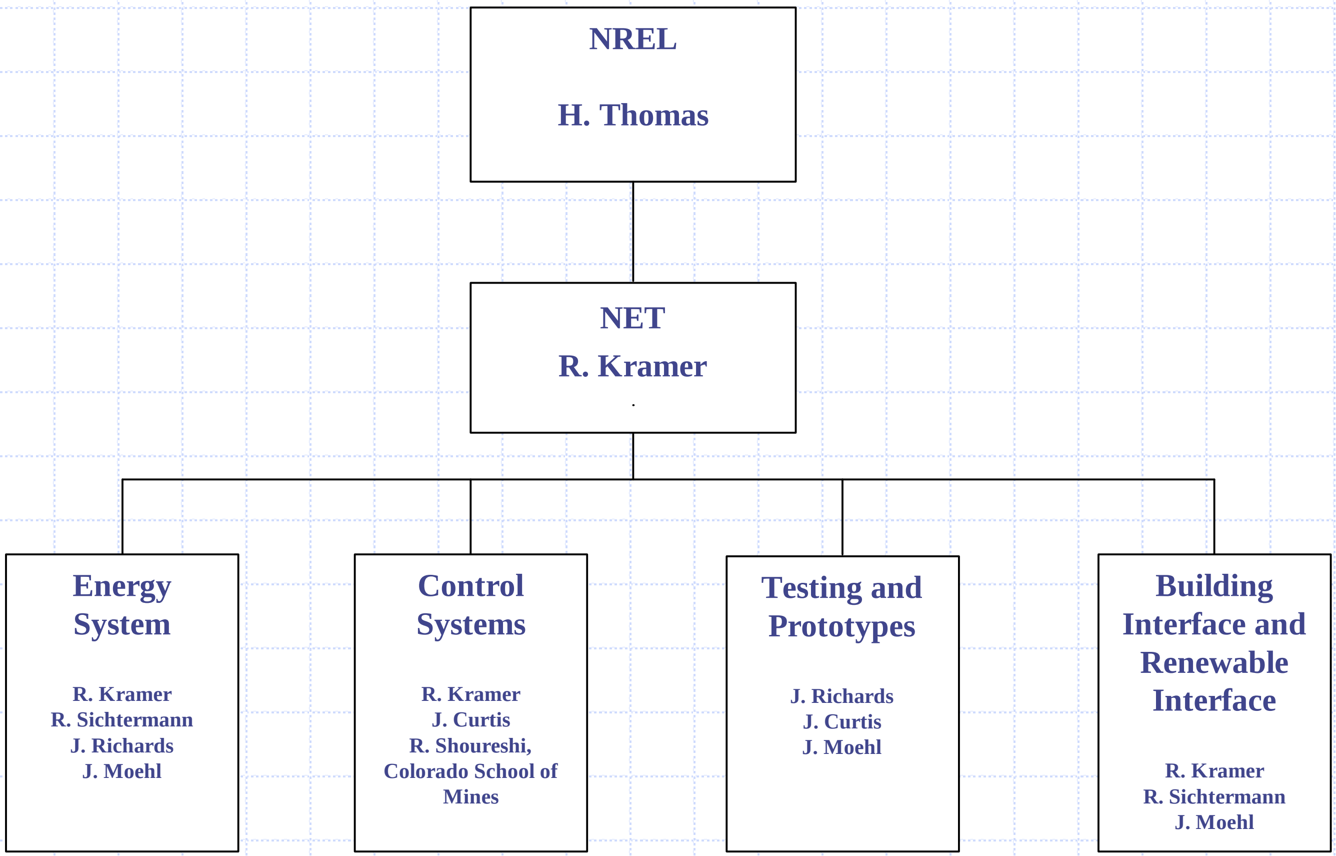
Basic Program Outline

- 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)
- Fully document, publish, and otherwise disseminate (through regional/national speeches, reports, and conferences) non-proprietary results and conclusions for maximum national replicability

Project Organization



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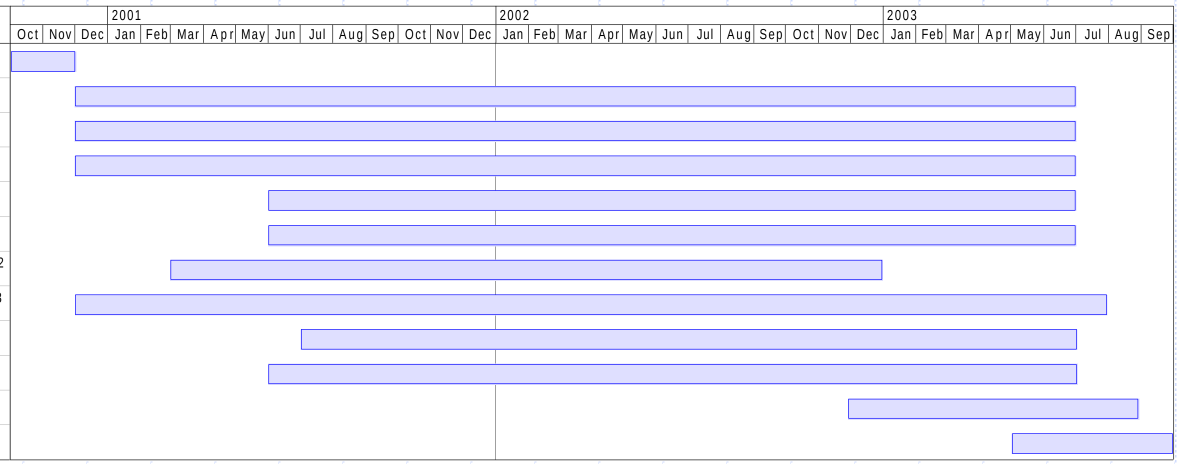
Project Schedule

Phase I | Phase II | Phase III

Task Name	Duration	Start	Finish
Project Scope Definition	45 days	Mon 10/2/00	Fri 12/1/00
Micro Turbine Testing	673 days	Fri 12/1/00	Tue 7/1/03
Fuel Cell Testing	673 days	Fri 12/1/00	Tue 7/1/03
System Controls	673 days	Fri 12/1/00	Tue 7/1/03
System Integration	543 days	Fri 6/1/01	Tue 7/1/03
Building Interface	543 days	Fri 6/1/01	Tue 7/1/03
Advanced System Control	479 days	Thu 3/1/01	Tue 12/31/02
System Optimization	694 days	Fri 12/1/00	Wed 7/30/03
Building Integration	523 days	Mon 7/2/01	Wed 7/2/03
Integrated Testing	544 days	Fri 6/1/01	Wed 7/2/03
Informational Meetings	196 days	Fri 11/29/02	Fri 8/29/03
Final Report	108 days	Fri 5/2/03	Tue 9/30/03



Milestones are monthly reports, yearly report, progress presentations, control report, and report on codes

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Phase II
Total Building Integration and System Optimization

- In this phase, the "system" will be the entire building (a comprehensive approach)
- Total building interface will be realized incorporating sustainable architecture, design, artificial intelligence and advanced controls, and interconnection with the larger grid.
- Research will include determining how a comprehensive distributed power building system performs, interfaces, and can be optimized with the electric grid.

Phase II Tasks

- Task 4: System Design
- Task 5: Interconnection
- Task 6: System Performance
  - Testing taking place at 3 test sites
    - 2 sites located in Gary, IN
      - Small office building (GTS1)
      - Warehouse (GTS2)
    - Commercial retail business located in Chesterton, IN

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System Design and Performance Issues

- To raise the efficiency of energy utilization from 21% to 70%+ it is necessary to use the excess heat to reduce other energy costs.
  - System integration into building and advanced controls
  - Heat utilization efficiency
- Reliability benefit
- Power quality benefit
- Grid interaction

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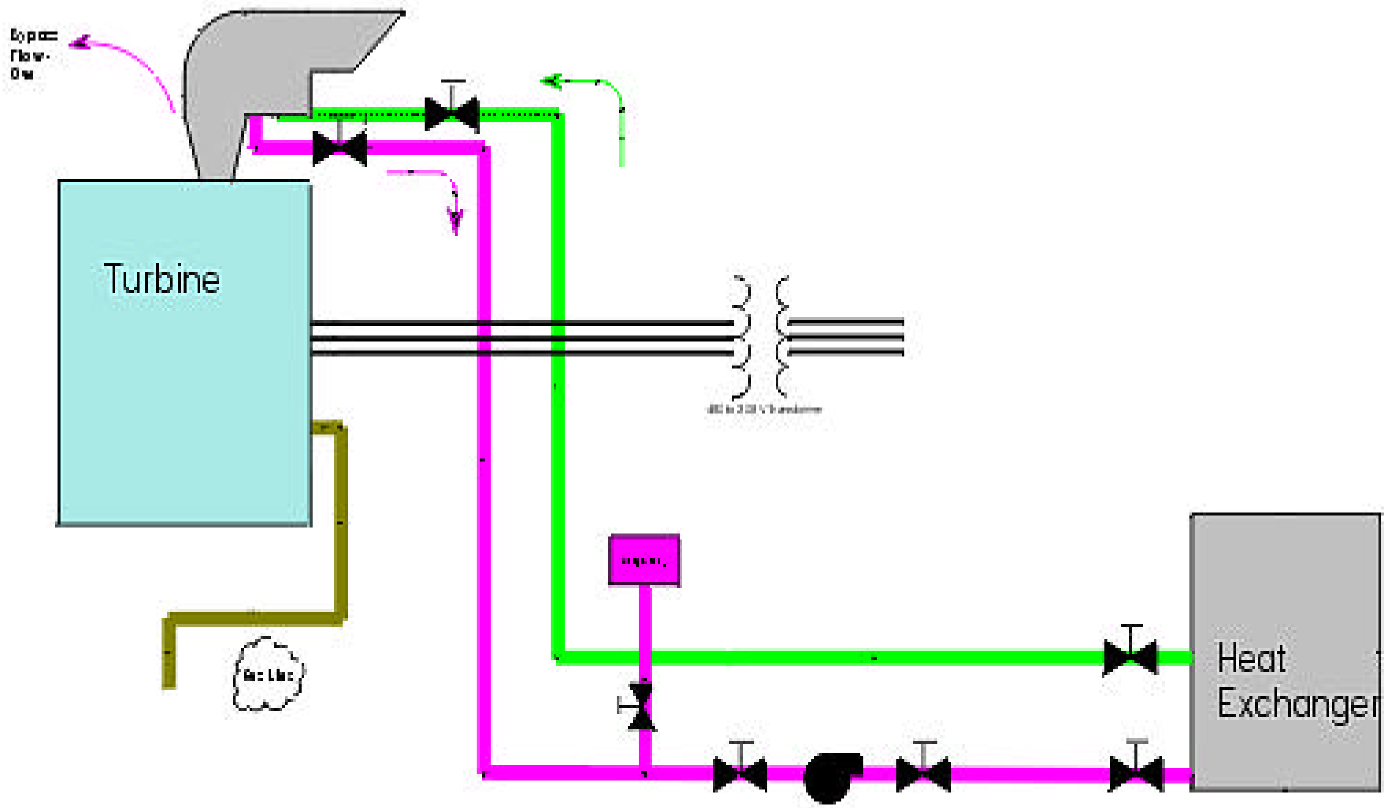
Basic CHP Heat Balance



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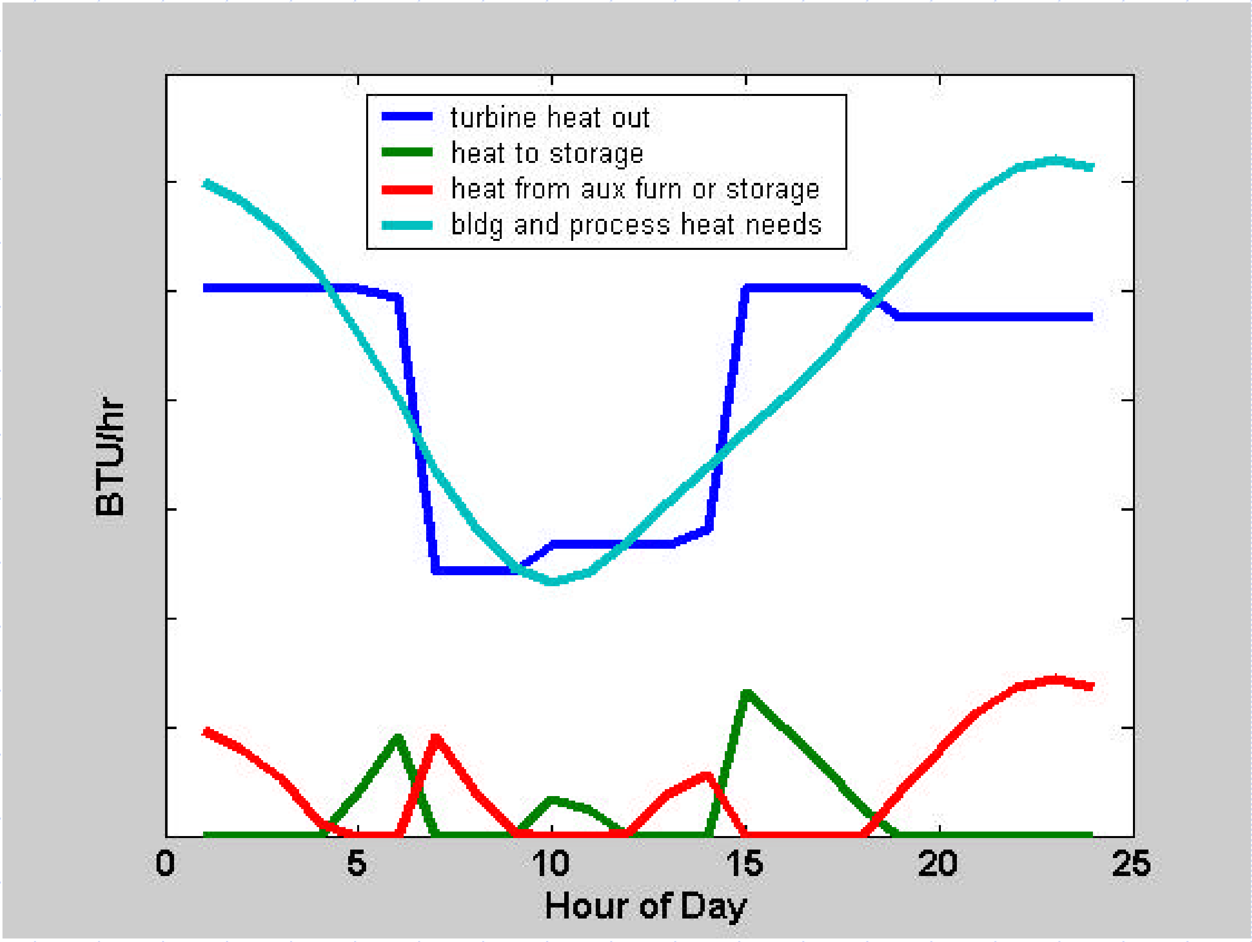
Commercial Building Heat Utilization Design for Winter



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Fast Response Heat Storage as a Means to Improve Energy Utilization

- Heat storage provides a means to improve overall energy utilization efficiency.
  - Shift the heat to times where it is needed rather than wasting it.
  - Storing and recovering the heat quickly increases its value over conventional thermal storage.

Fast Response Low Temperature Eutectic Heat Storage Test Unit

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Copper Tubing for Fast Response Heat Storage

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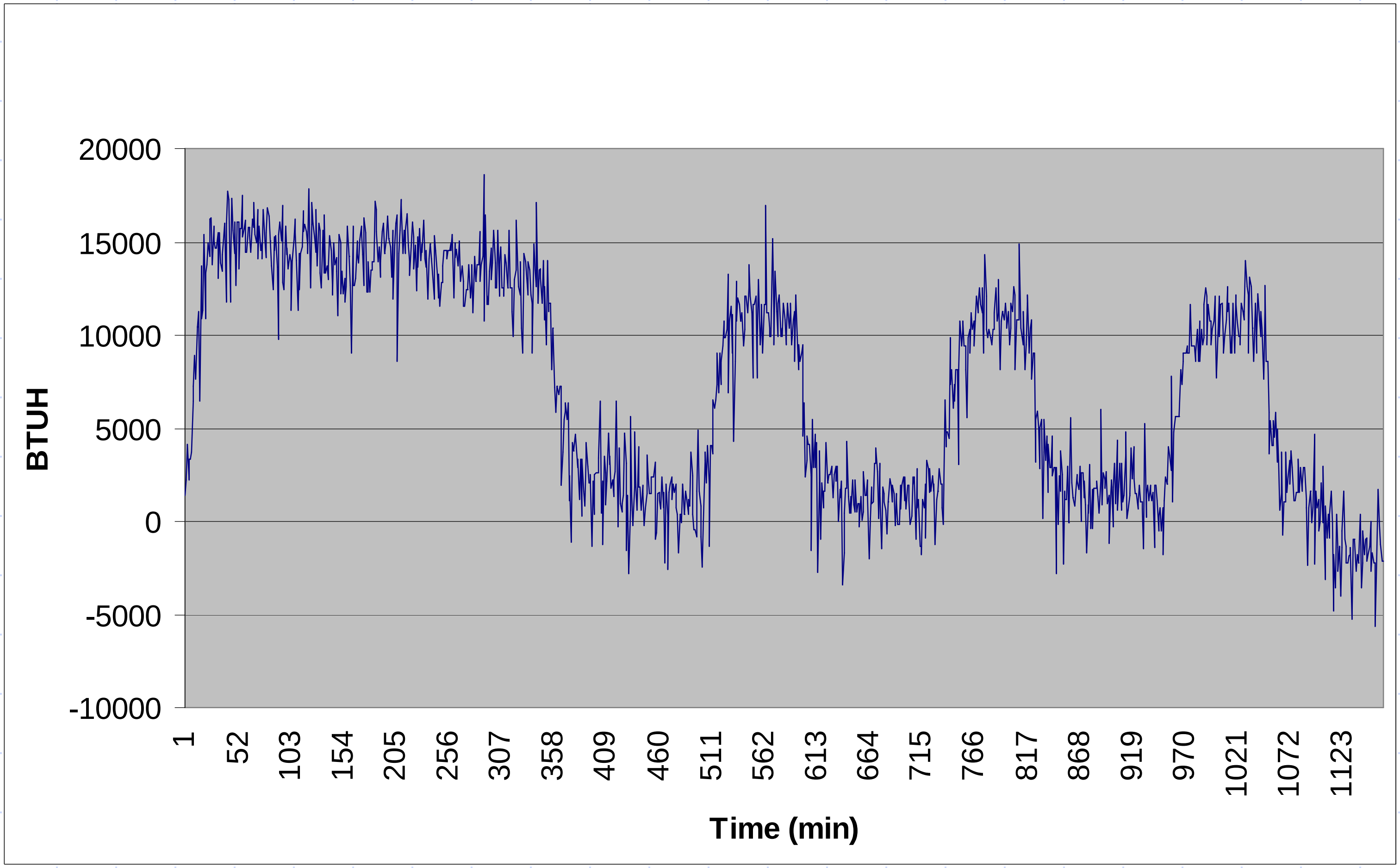
Heat Storage Performance Results 5/29/02 Heat Addition to Mass



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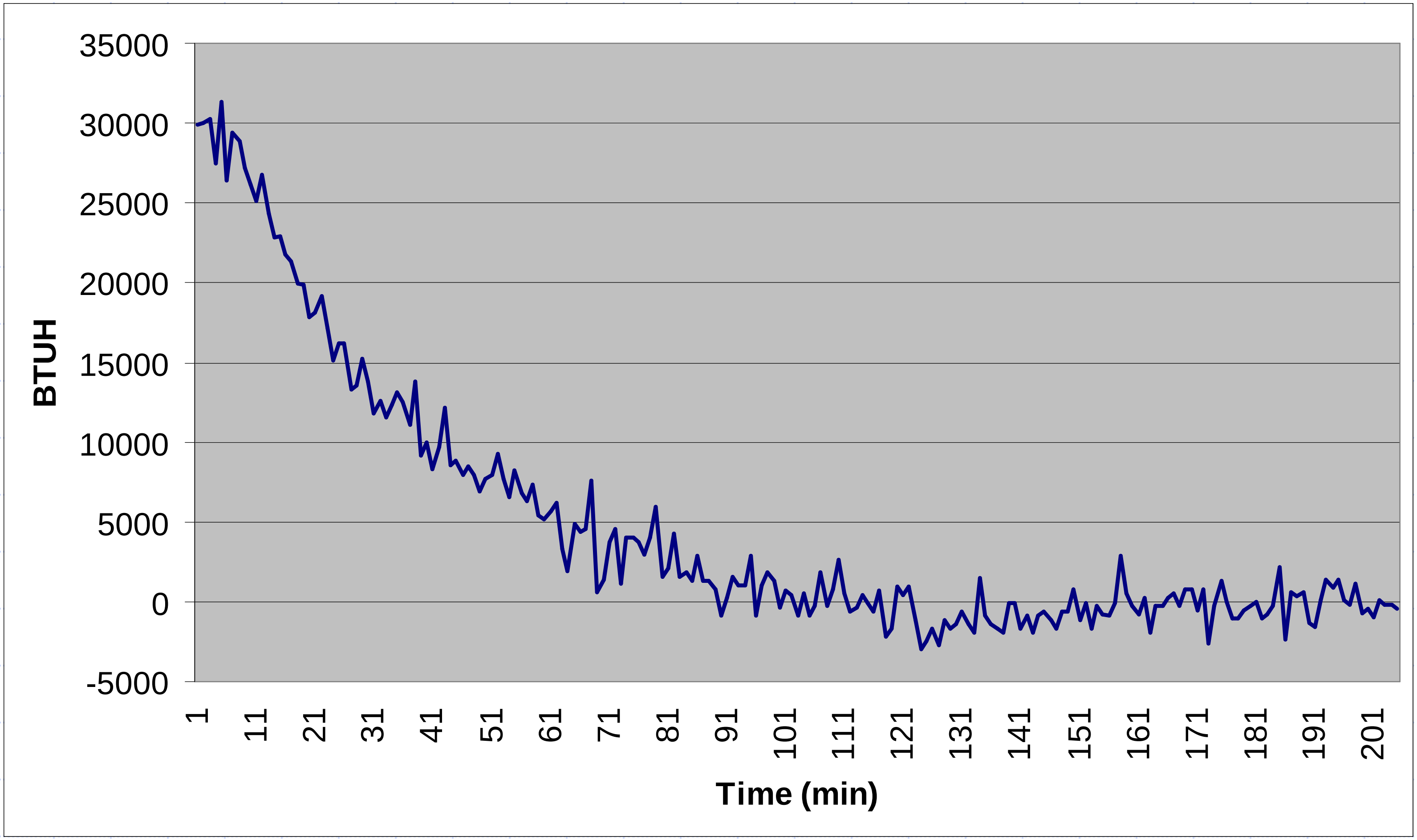
Heat Storage Performance Results 5/29/02 Heat Extraction From Mass



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Desiccant Dehumidification Uses Heat and Reduces Electric Requirements

- Waste heat can be used to regenerate desiccant dehumidification systems.
  - A small commercial system is being tested at GTS1 and a custom system is being tested at Chesterton test site. A desiccant system is planned for GTS2.
- As humidity is reduced, the room temperature can be increased thereby reducing electric air conditioning costs.

GTS1 Desiccant Unit

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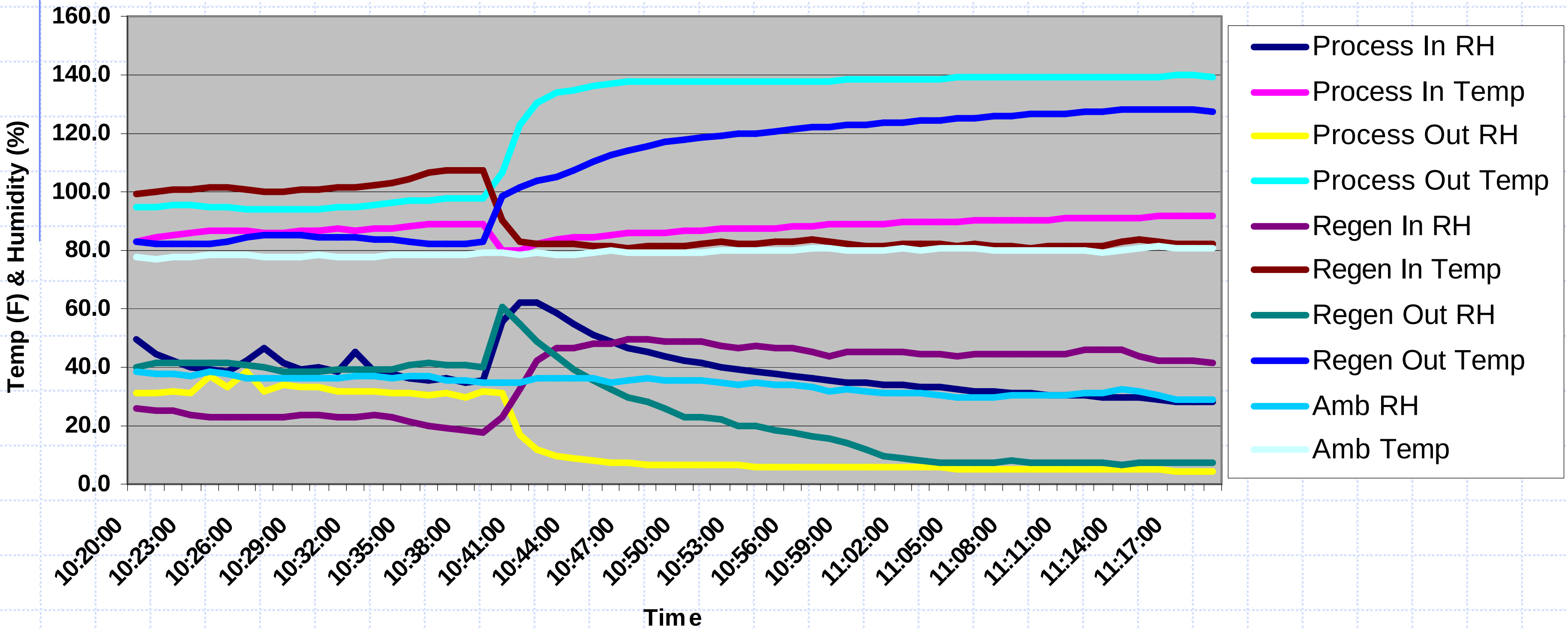
GTS1 Desiccant Test - June 18, 2002



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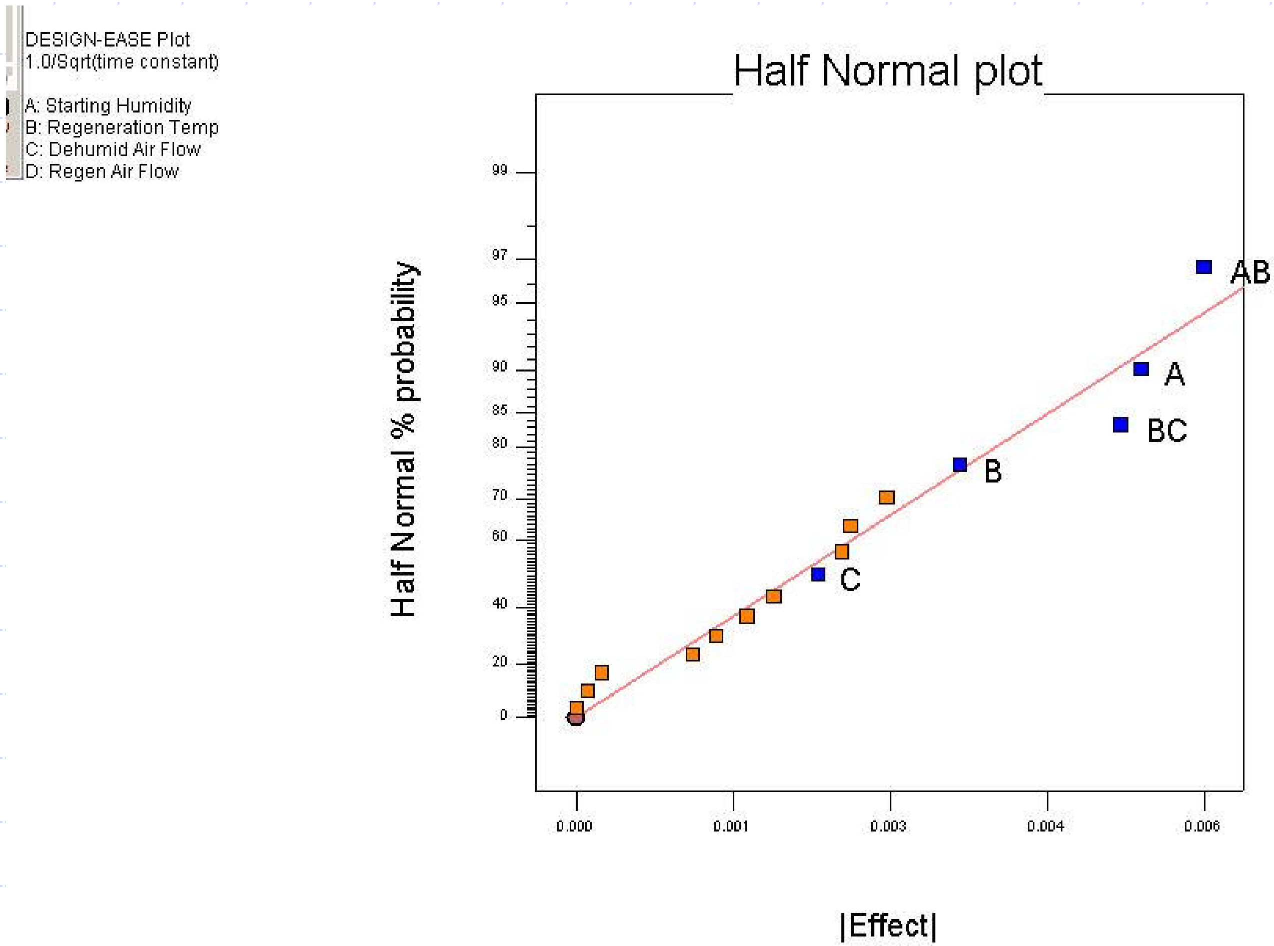
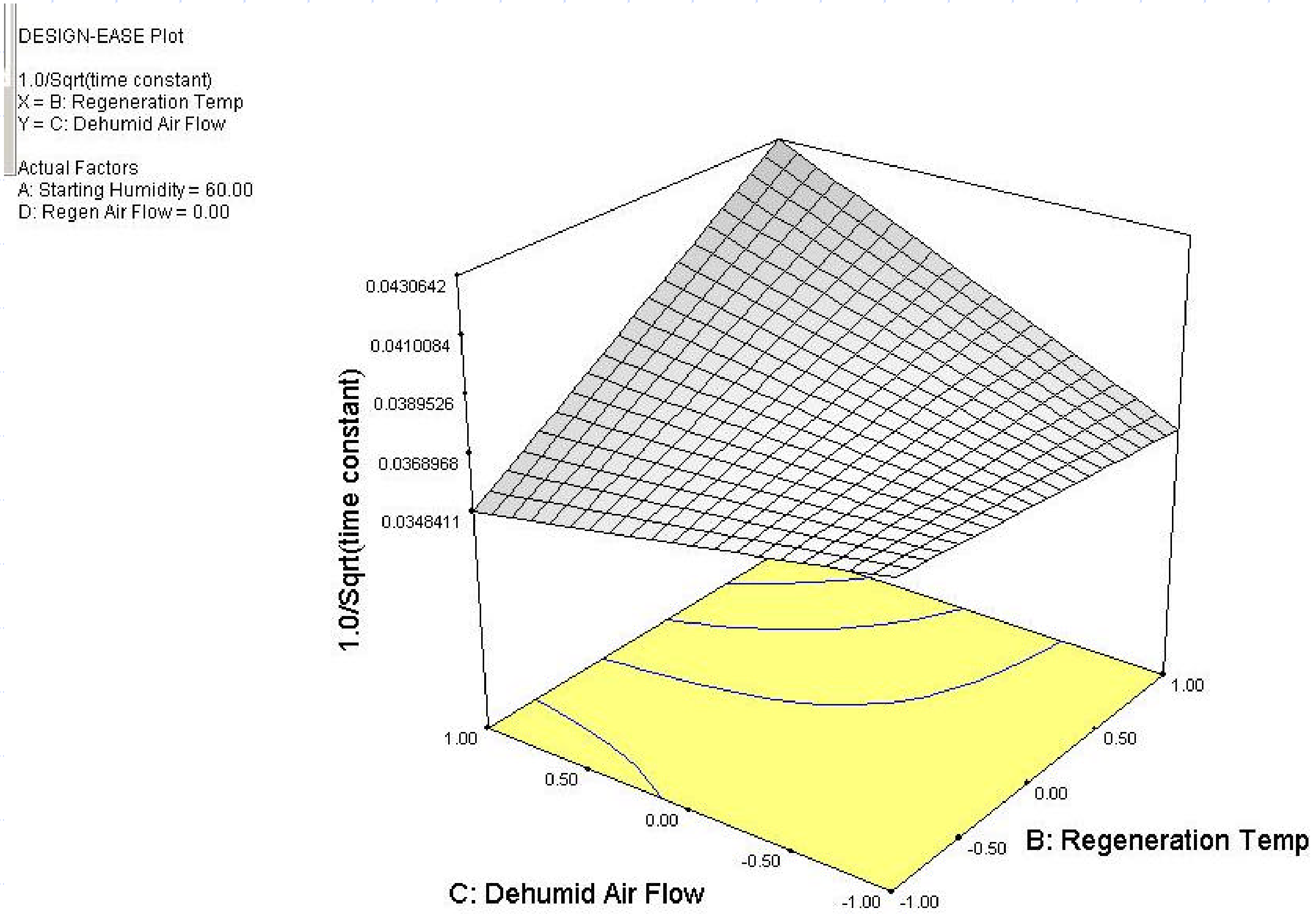
GTS1 Desiccant Test – Time Constant Statistical Test Example



GTS1 Desiccant Test – Time Constant Statistical Test Example



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Chesterton Test Site Desiccant Unit

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Building Model As Part of Determining the Optimal BCHP Mix

- Quick running model written in MathCad is being used for Gary test sites.
- Optimizing dynamic MatLab model is being developed for Chesterton test site.
  - True dynamic model
  - Neural networks
  - Fuzzy logic

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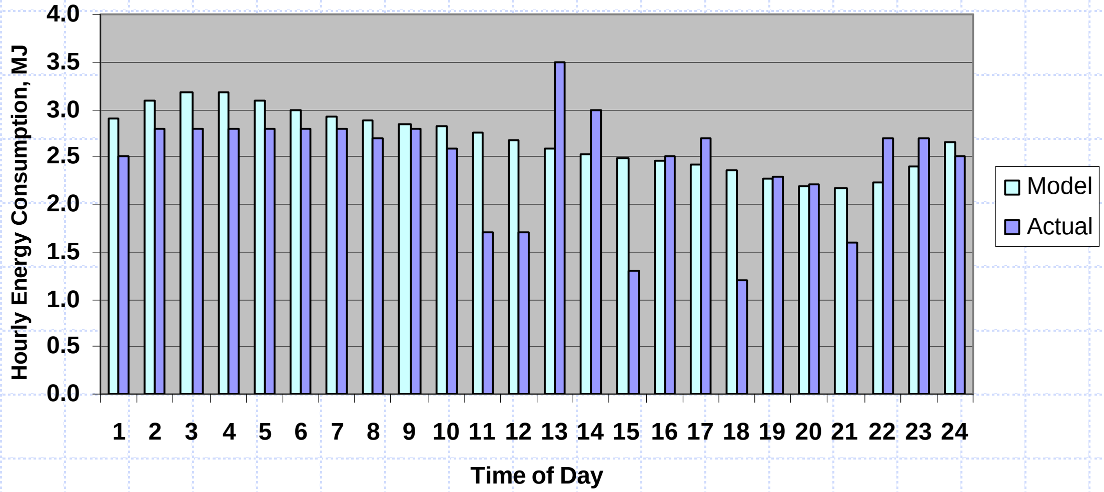
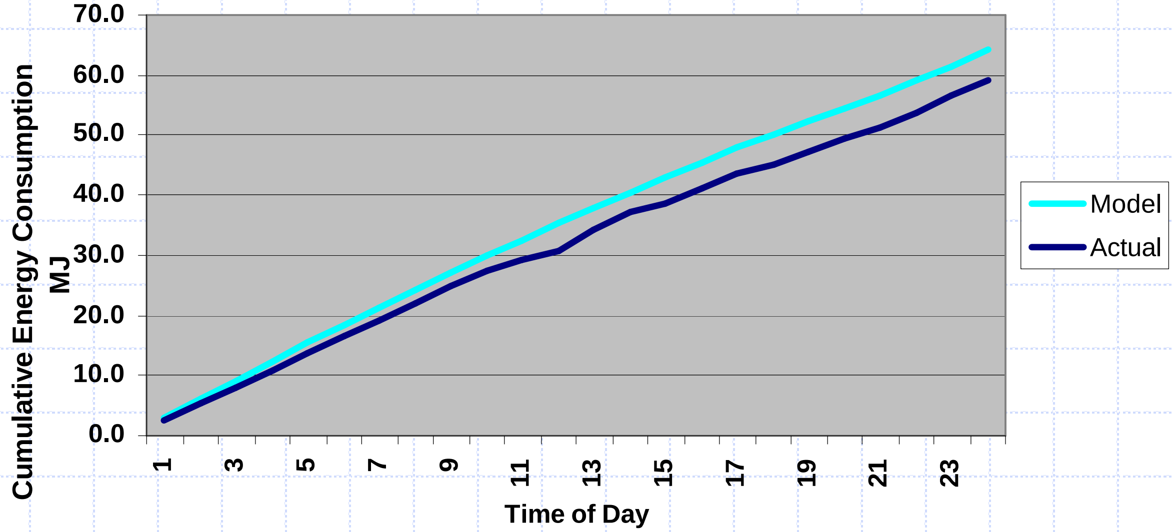
GTS1 Building Model Comparison 5/16/2002 - 5/17/2002





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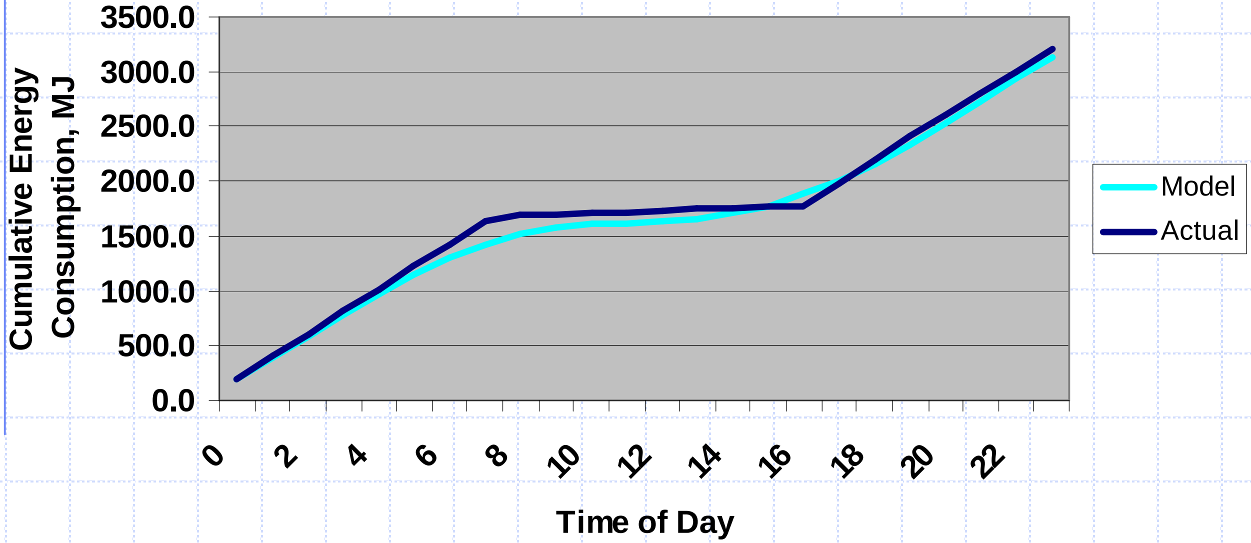
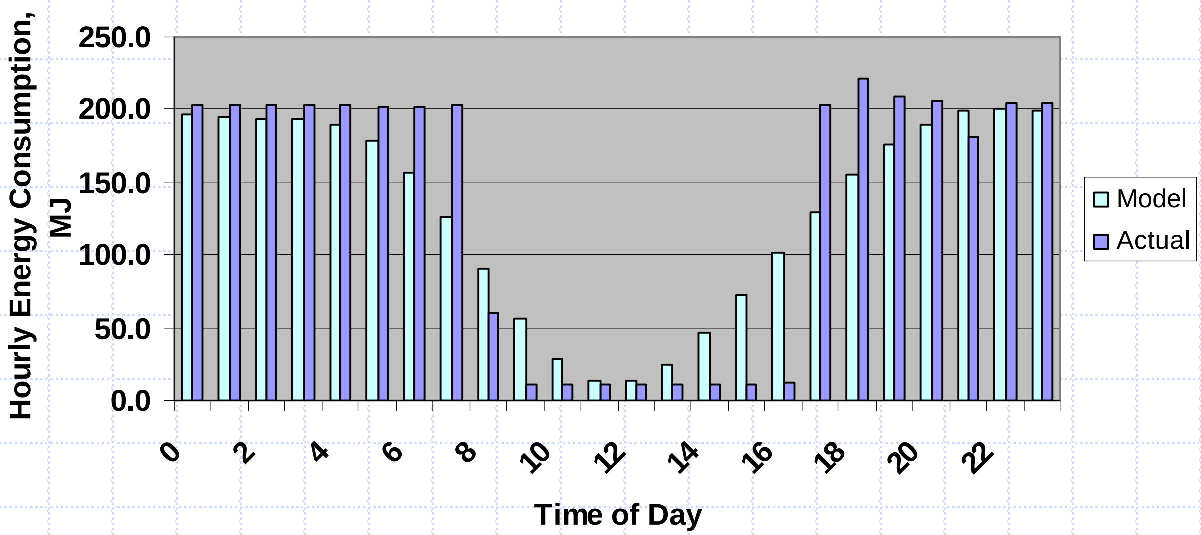
GTS2 Building Model Comparison 6/14/2002 - 6/15/2002





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CHP Module for Gary test site

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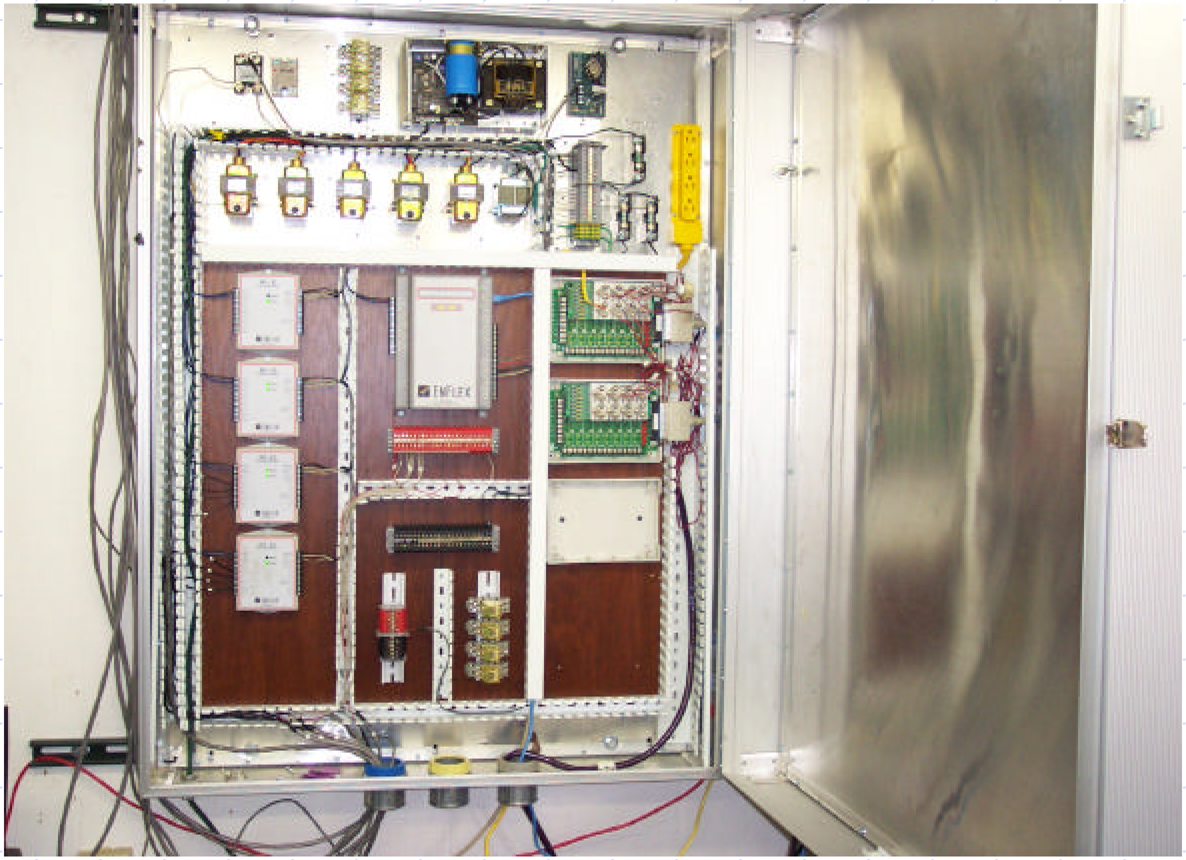
Controls for GTS1 and GTS2



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CHP Heater for GTS1

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GTS1 Energy Recovery Vent (ERV) (Desiccant Based)

Future Activities for GTS1 for Phase II

- Testing of energy recovery vent (desiccant based)
- Inclusion of experimental sunlight values in building model and further refinement of model
- Performance and appraisal of CHP desiccant and energy recovery vent in parallel
- Absorption cooling performance in combination with desiccant and conventional air conditioner.
- Appraisal of influence of desiccant on temperature comfort range
- Optimization of CHP based heating, cooling, and dehumidification in conjunction with passive solar heating options.

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Influence of Electric Storage Device on GTS2 CHP System

- Fly wheel system is being interfaced to CHP system to consider interactions and optimization possibilities.
- Interactions between power electronics and with the grid.
- Power Quality Implications

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Future activities for GTS2 for Phase II

- Interaction of desiccant dehumidification, absorption cooling, and heating on warehouse operation
- Expansion of the building model to include 2 diverse regions of the building
- Optimization of CHP energy use for warehouse applications
- Consideration of application of the technology to other industrial applications
  - Reducing the corrosion of stored steel
  - Influence on productivity
  - Influence of building conditions on storage of substation electric components

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Chesterton Test Site Development

New Refined System

Initial Test System

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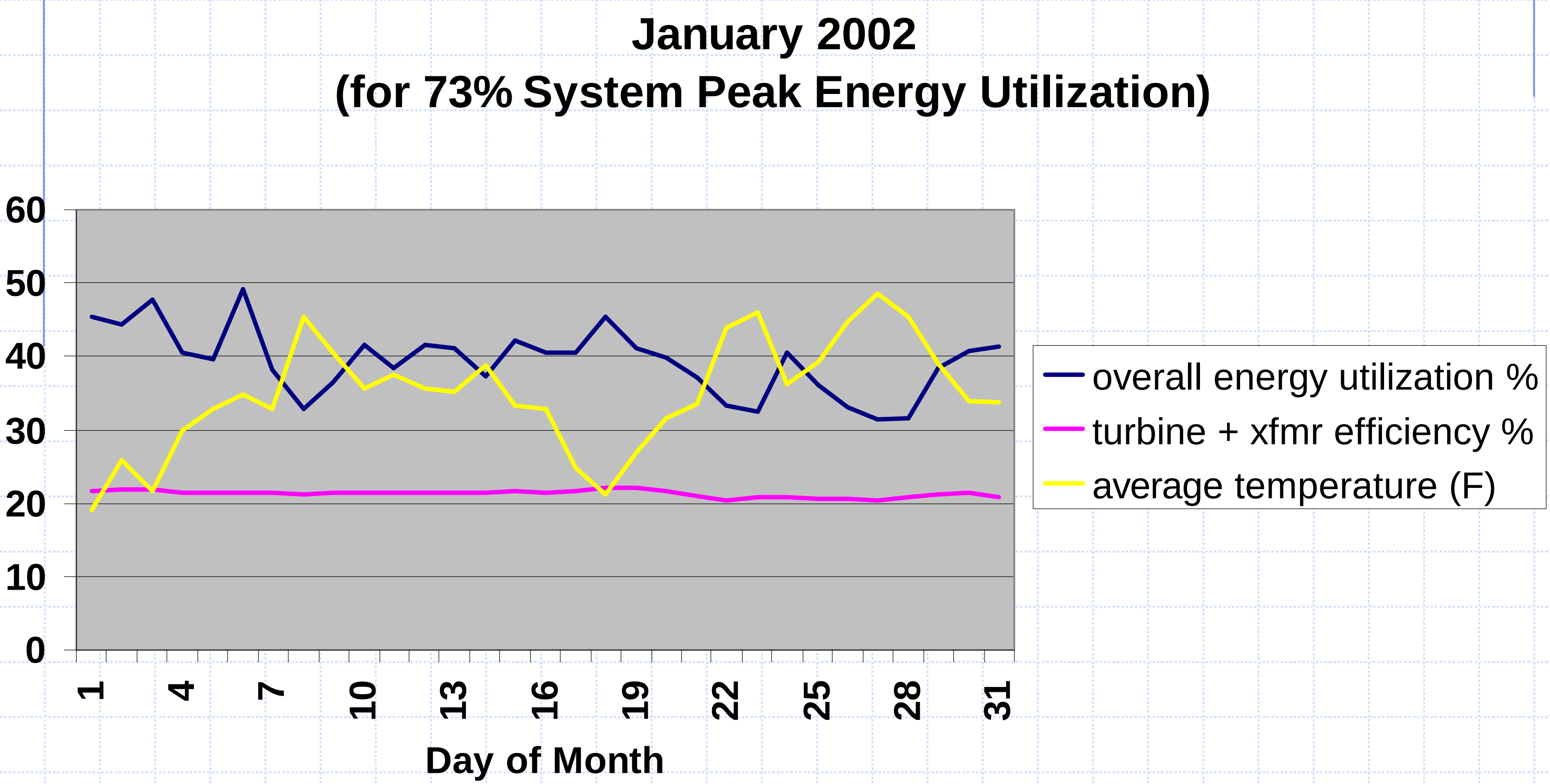
Chesterton Test Site Energy Utilization (Not Optimized)



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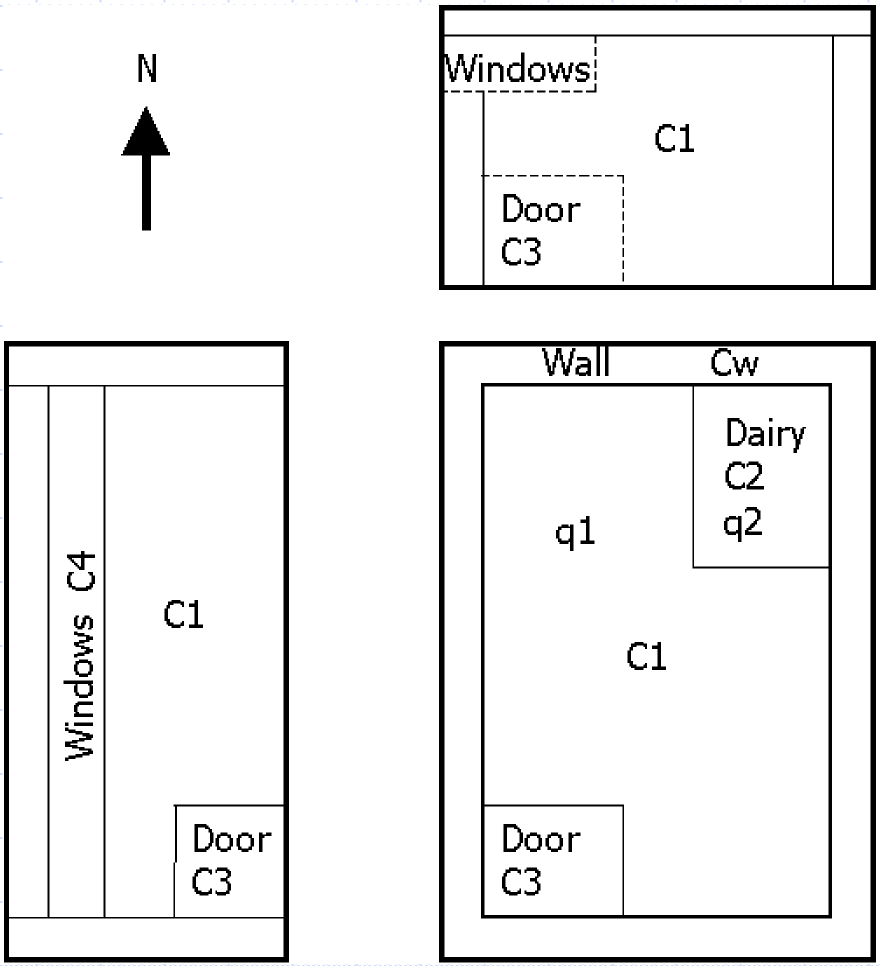
Chesterton Site Building Model Zones



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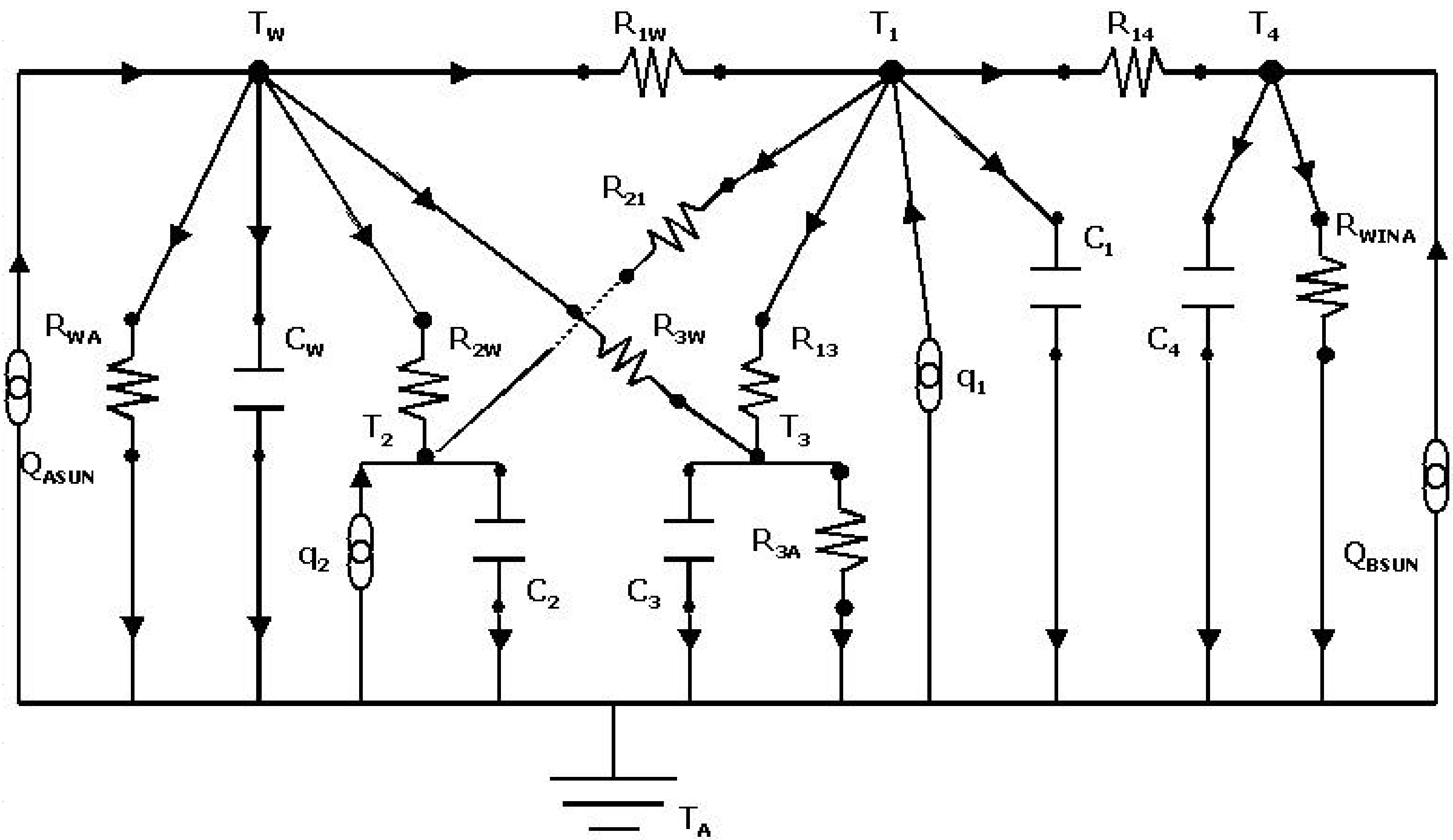
Chesterton Site Thermal Equivalent for Building Model



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Electric System Interaction Considerations

- Detailed PQ data is being obtained and analyzed
- Bump less transition on loss of grid power
- Fast transition on restoration of grid power
- Consistency with proposed IEEE and other standards

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Future Activities for Chesterton Test Site for Phase II

- Completion of dynamic building model and benchmarking with field data for all subsystems
- Optimization of 5 thermal zones with heat flow between zones
- Implementation of neural networks and fuzzy logic to improve energy efficiency and economics.
- Optimization of electric, heating, and desiccant systems to reduce operating costs
- Reformulation of building control program to improve CHP performance under diverse weather conditions

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Interconnection Considerations

- Determine important electric distribution system features for CHP
- Influence of costs and delays
- Interconnection approaches and standards
- Review and identify critical building and electric code requirements
- Influence on CHP optimization activities

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Phase III - (Next Year) - Advanced "System" Interconnection and Affects

- Study the interface between and among multiple building systems with varying power requirements, usage trends, generation sources, and control systems on each other and the entire grid.

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