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Challenges in Industrial Waste Heat Recovery

Texas Technology 2006 Showcase

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Outline

- Plant Statistics and Energy History
- Tools Used to Identify Projects
- Sample of Projects
  - Completed
  - Working
- Conclusions

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Plant Statistics and Energy History

- Plant Site
  - Over 900 acres
  - 1 to 2 million lb/hr steam generation
    - 600 psig, 150 psig, 75 psig and numerous LP systems
  - 700 employees
  - Over 2 billion lbs of product shipped annually
  - Multiple operating units
    - Independent steam producers and steam consumers

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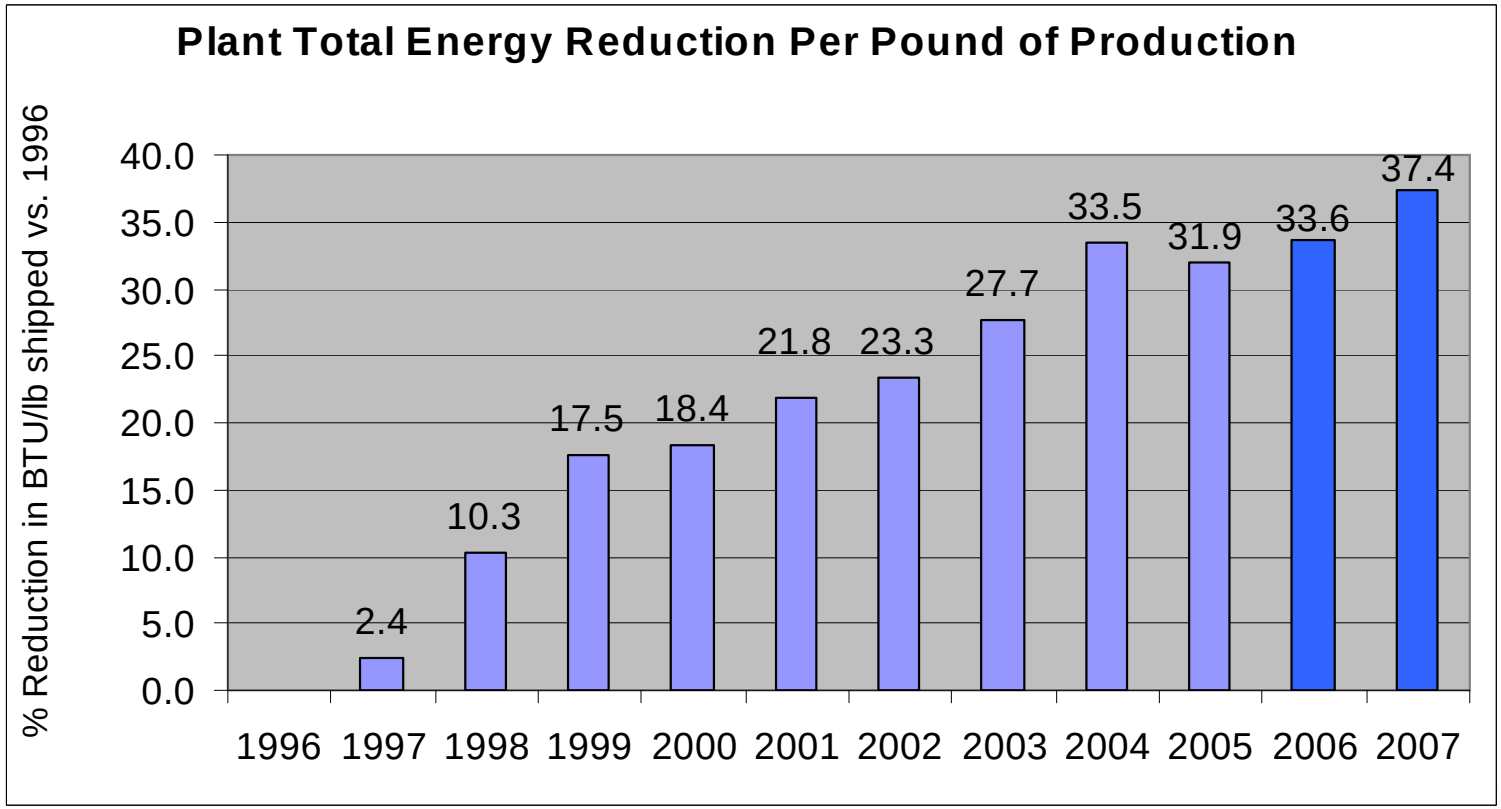
Plant Statistics and Energy History

- Energy Program started in 1996
- 34% reduction in BTU/lb product by 2004
- Over 100 projects/operational initiatives completed



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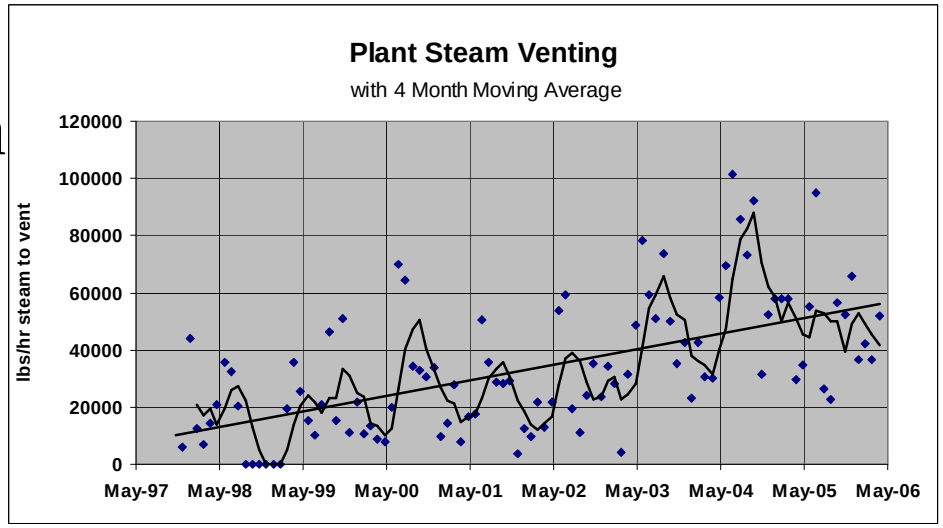
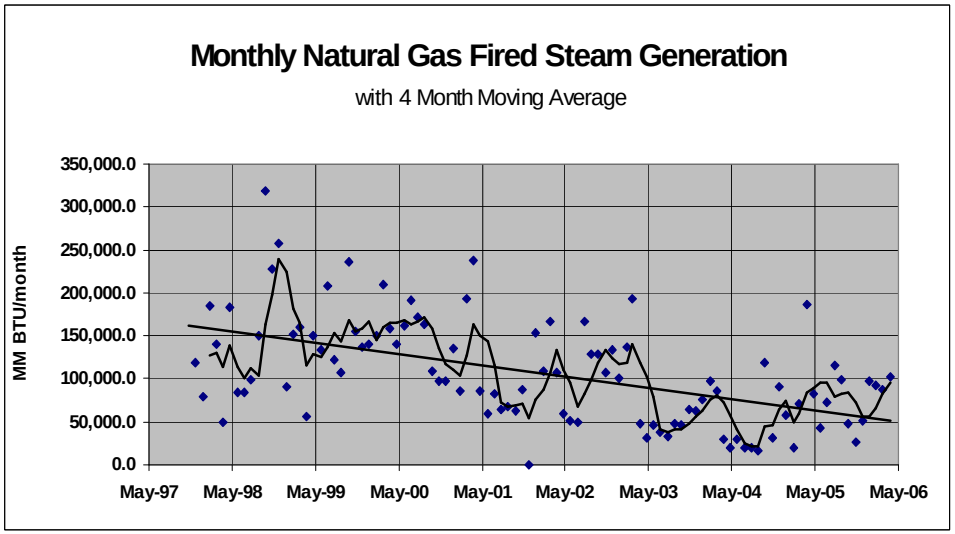
Plant Statistics and Energy History

- Past efforts focused on
  - Direct natural gas reductions
  - “putting steam in the pipes”
- Result is
  - Increased frequency of steam venting
  - Reduction in purposefully fired steam





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Plant Statistics and Energy History

- **Challenge** – Waste heat recovery projects can't use 100% of the energy savings in project justifications! "Waste heat steam - use it or lose it"
  - Recovery of waste heat has value less than 100% of the time
  - Conversely, use of excess steam has less than 100% utilization
  - Heat recovery and steam consumer projects are harder to justify

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Tools Used to Identify Projects

- Site Energy Assessments
  - Structured process or unit assessments
  - Steam trap and leak audit
  - Compressed gas audit
  - Infrared survey
  - DOE basket of assessments

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Tools Used to Identify Projects

- Develop / Update Plant Steam Balance
  - Commercial software makes this easier
    - Real-time studies over various periods
  - Identify imbalances, pressure letdown opportunities, high flash losses and condensate return options
- Determine Utilization of Existing Heat Recovery Systems
  - Histograms and Monte Carlo analysis useful
    - Steam Supply/demand imbalances can be quantified

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Tools Used to Identify Projects

- Site and Sub-System Heat and Material Balances
  - Identify Inefficiencies and Opportunities:
    - High approach temperatures on exchangers
    - Process Cross-exchange heat transfer opportunities
    - Poor power conversion - pumps, compressors, % load
    - High stack temperatures – boilers, heaters, furnaces, gas turbines
    - High boiler blow-downs and excess oxygen
    - Condensate return opportunities
    - Flared or waste streams with fuel value
    - High temperature loads to cooling tower or air coolers

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Tools Used to Identify Projects

- List all natural gas/fuel consumers and evaluate potential reductions

- Pinch Analysis
  - Target cross pinch heat transfer

- Quantify and Match Heat Sources and Sinks
  - List available heat sources, duties and temperatures
  - List heat sink sources, duties and temperatures
    - Air and water common sinks
      - Air preheat increases NOx on combustion equipment

Tools Used to Identify Projects
Value of Steam

- Boiler efficiency may be 80%, but steam for consumption in the plant (steam system efficiency) will be less
- See DOE Best Practices Steam Technical Brief How to Calculate the True Cost of Steam
- If steam venting occurs, use a factor for % utilization of steam (recovered or used)

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Completed Projects

- Capital
  - Process Waste Heat Boiler increase in surface area
  - Parallel 600# steam line to reduce pressure drop, allowing export of steam vs. venting at high rates
  - Condensate return frequency improvements by piping modifications to reduce dP
  - Repair bypass on second stage compressor intercooler

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Completed Projects

- Operational
  - Stop slow roll of steam turbine
  - Lower 75# header pressure, reduce multiple steam turbine exhaust pressures and frequency of venting
  - Improved DI water quality allowing for a 60% increase in boiler cycles
  - Automated pressure control for excess 600 # steam pressure
  - Clean waste heat boiler surfaces

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Completed Project

- Insulate hot 130C propylene line to reactor
  - 3.5MMBTU hr of low level heat kept in system to produce high level steam in reactor
  - Savings from reduced natural gas fired steam
  - 1 year payback at $6 gas with steam valued 50% of the time

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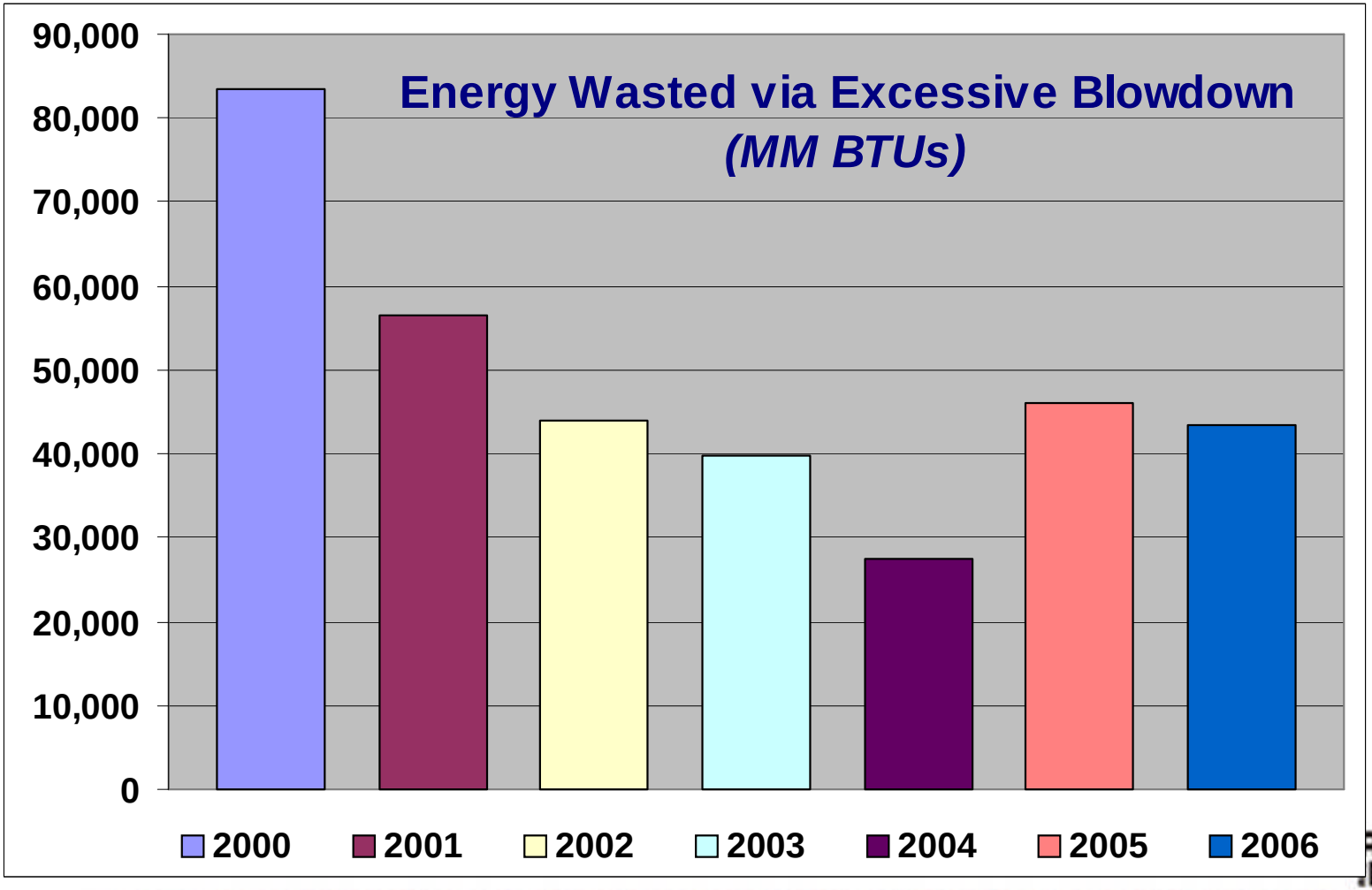
Completed Projects

- Reduction in Boiler Blow-down – requires continuous surveillance



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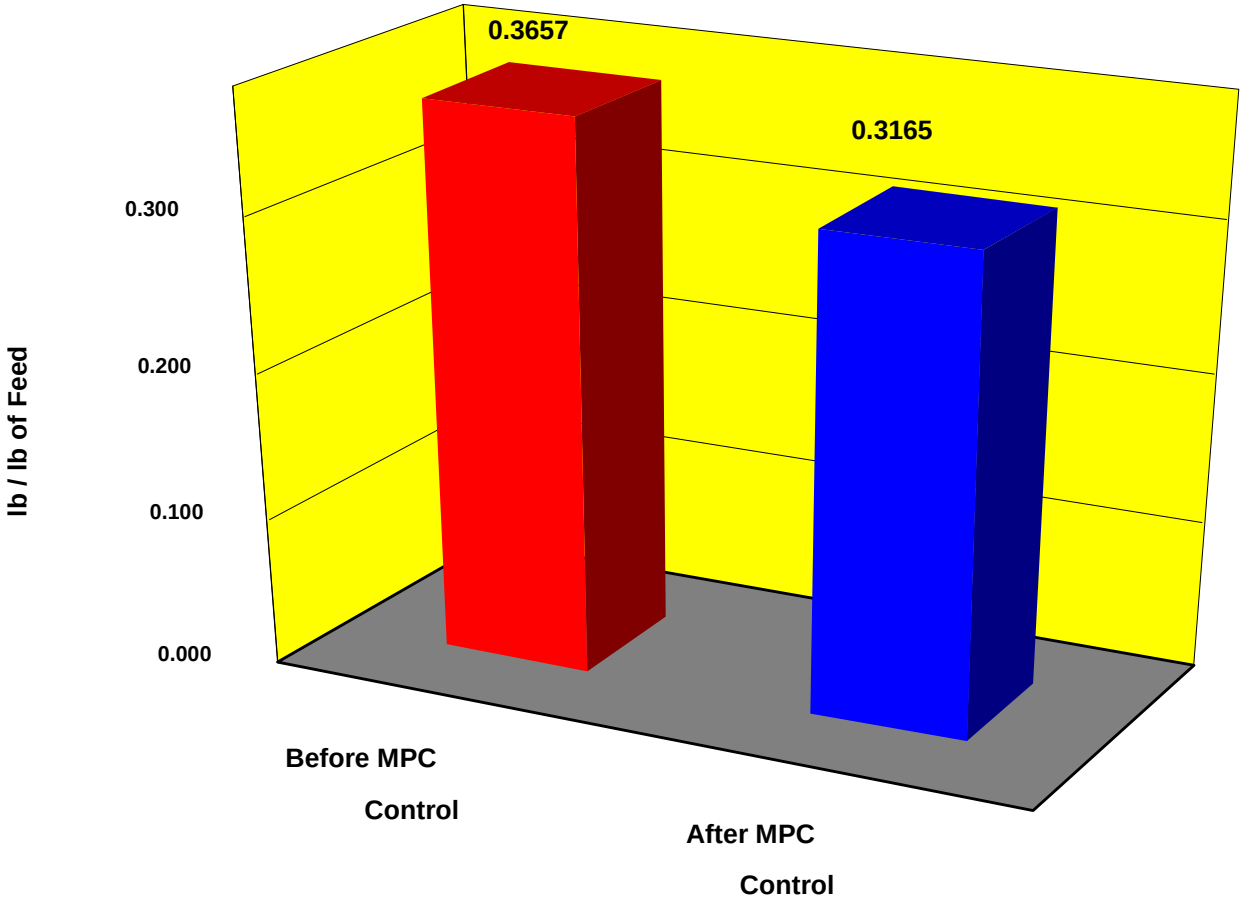
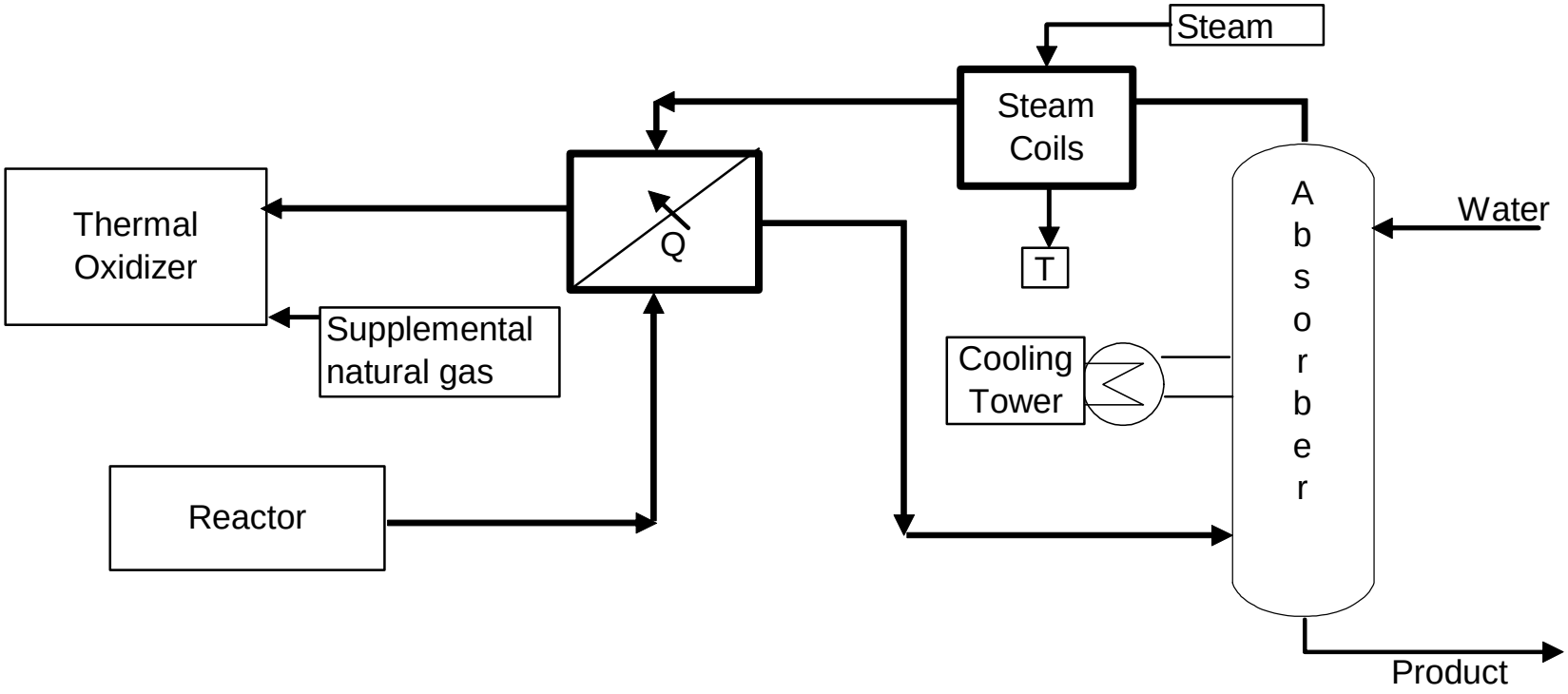
Completed Project
Model Predictive Control -14% Steam Reduction in Distillation Operation



Working Project - Gas to Gas Process Exchanger

- Heat recovery of 15 – 20 MMBTU/hr
- Gas to Gas – more surface area for heating



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Working Project - Gas to Gas Process Exchanger

- Reference US patent 2004/0143149

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Working Project

- Increase condensate recovery frequency from several local reboilers
  - Problem was pump NPSH
    - Solution was regenerative turbine pump
  - Installed in 1999
    - Ran ok until production rates crept
    - Regenerative turbine pump has fixed capacity
    - Results in overflow of tank at high rate operation
  - Current plan is to install centrifugal pump with cooling of condensate on pump suction by DI water injection

Working Project - Steam Turbine to Replace Gas Turbine

- Current Configuration
  - GE Frame 5 gas turbine with HRSG driving a multi-stage multi-case air compressor
- Plant steam balance results in venting majority of steam produced in HRSG, and is projected to increase
  - Simple cycle operation averaging ~22,500 BTU/Kw-hr when no steam demand
  - Poor turndown with respect to energy and limited air compressor capacity at high end
  - Gas turbine makes more steam with higher rates
    - Poor fit for plant that vents steam more as rates increase

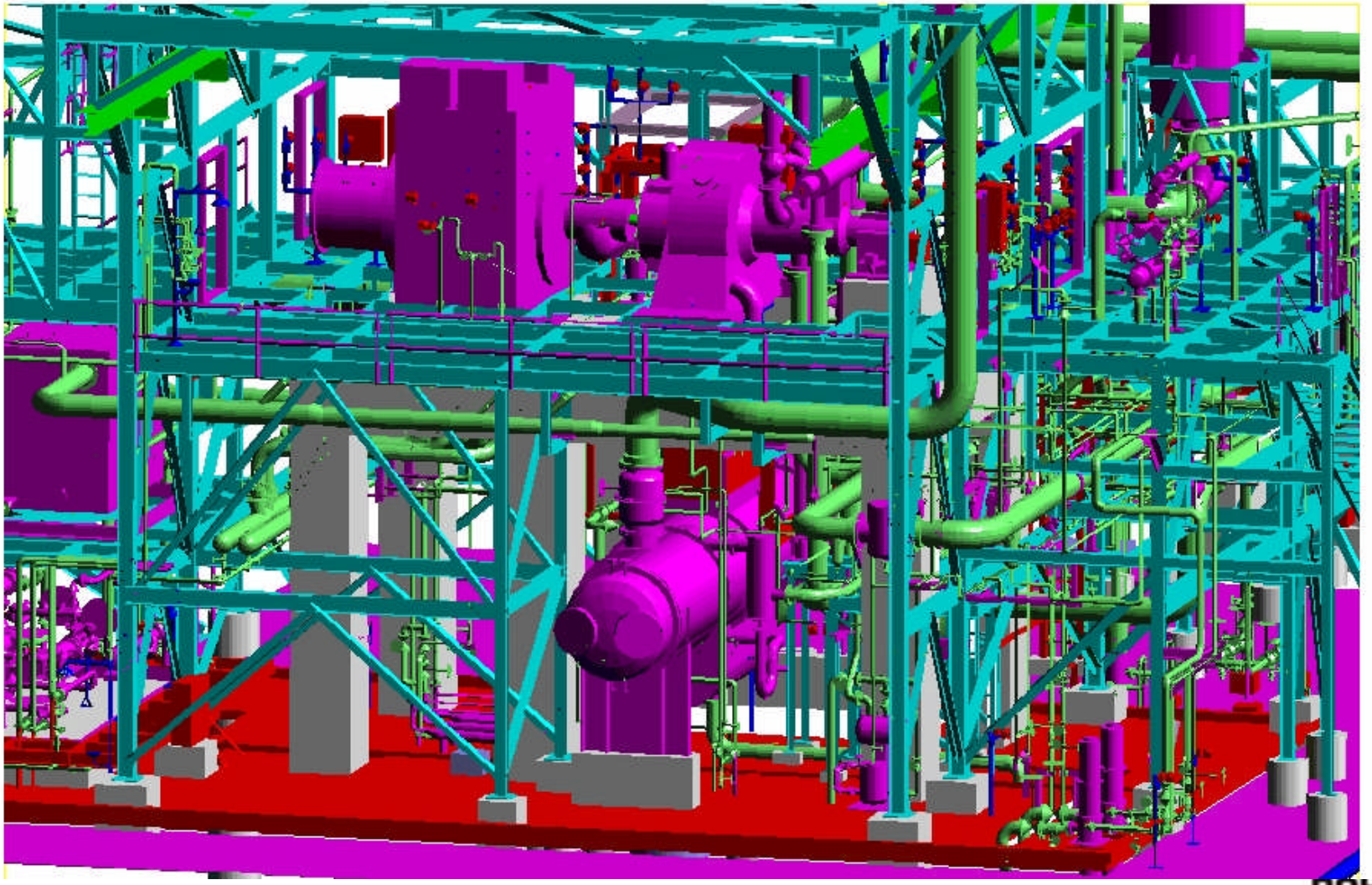
Working Project - Steam Turbine to Replace Gas Turbine

- Planned Changes
  - Shutdown gas turbine /compressor system
  - Install new condensing/extraction steam turbine with new compressor
    - Grassroots location
- Start-up Q2 2007

Working Project - Steam Turbine to Replace Gas Turbine

- Benefits
  - Plant air emission reductions expected
    - NOx reductions of 80 tpy
    - CO reduction of 95 tons/yr
    - CO2 reductions of 47,000 tons/yr
  - Increased use of letdown steam for power
  - De-coupling of steam production with process rates
  - New compressor more efficient
    - 12,500 hp vs. 13,700 hp at same operating point
  - Turbine extraction flow can handle 50% of power needs
  - Full condensing capability
  - Condensing steam rate of 7.4 lbs/hp-hr

Working Project - Steam Turbine to Replace Gas Turbine



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Working Project - Steam Turbine to Replace Gas Turbine

- Heat Rate Comparison in BTU/Kw-hr & (cycle efficiency):
  - Gas Turbine Simple Cycle 22,520 (15%)
  - Gas Turbine Combined Cycle 12,690 (27%)
  - Steam Turbine full extraction 12,440 (27%)
  - Steam Turbine full condensing 19,946 (17%)
  - Effective Heat rate for purchased power at $7 nat gas and $0.08/Kw-hr 11,429 (30%)
  - Turbine Letdown power 5,000 (68%)

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Challenges in Waste Heat Recovery Conclusions

- 100% of energy value is not economic value
  - However, with natural gas 2-4 times the cost when many processes were designed, lower utilizations still have reasonable payback.
- Preheating a common low temperature source of air to a combustion unit leads to higher NOx generation
- Heat recovery utilization improvements generally require continuous effort to sustain

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Challenges in Waste Heat Recovery Conclusions

- Current market environment has doubled the cost of similar projects in the last 2 -3 years
- Combine heat recovery projects with end of life, environmental and reliability improvements
- Flexibility in managing steam systems is key to high waste heat utilization

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