Challenges in Industrial Waste Heat Recovery

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Outline

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

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

- Reduction in Boiler Blow-down – requires continuous surveillance

![Bar Chart: Energy Wasted via Excessive Blowdown (MM BTUs)]
Completed Project
Model Predictive Control - 14% Steam Reduction in Distillation Operation

Before MPC Control

After MPC Control

lb/lb of Feed

Before MPC

After MPC

0.3657

0.3165
Working Project - Gas to Gas Process Exchanger

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

- Reference US patent 2004/0143149
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
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%)
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
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