Optimizing Energy Saving Opportunities in Food and Dairy Plant Steam Boiler Systems

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Introduction

• Food & Dairy Plants typically employ 100-135 psig steam generated by firetube boilers.
• First cost of a steam boiler plant is exceeded many times by the cost of energy over the life of the boiler plant.
• Numerous opportunities are available to reduce lifetime energy costs, some of which are addressed in this presentation.
• It is the design and/or plant engineer’s responsibility to evaluate the opportunities for energy savings and where appropriate to justify added first costs with payback analysis.
Goals

• Review System Design Basics
• Rules of Thumb
• Model Plant
• Evaluate Opportunities for Energy Savings
System Design Basics

- Proper match of boiler(s) size to steam demand by use of a Gantt chart
- Appropriate feedwater treatment
- Design for maximum condensate return
- 5 sq. ft. of heat transfer surface per boiler hp
- Proper burner to boiler mating
Rules of Thumb

- A 10 psig drop in steam pressure = 1% energy reduction
- 1% increase in boiler efficiency for every 40°F decrease in stack temperature
- 1% increase in boiler efficiency for each 15% reduction in excess air
- 1% increase in boiler efficiency for every 11°F increase in feedwater temperature
Model Plant (used for basis of evaluations)

- Meat processing plant with two 500 hp firetube boilers, 4/1 turndown burners firing 1000 Btu/0.6 S.G. natural gas, 100 psig operating pressure, 80% fuel to steam efficiency, continuous surface blowdown
- Six days/week operation, 50 weeks/year
- 20 hours/day production, four hours/day cleanup
Model Plant (continued)

- Steam loads:
  a. Connected: 1225 hp
  b. Production demand: 875 hp
  c. Cleanup demand: 245 hp
  d. Weekend/holiday demand: 105 hp

- Tray type deaerator operating @ 5 psig, softened make-up water and 80% condensate return

- Gas Cost: $8.35 per decatherm

- Annual fuel costs: $1,600,000/year
Opportunities for Energy Savings

- Operation at lowest possible steam pressure
- Burner turndown
- Economizers
  a. Noncondensing
  b. Condensing
- Surface blowdown heat recovery
- RO make-up water treatment
- O₂ trim control
## Steam Pressure Reduction

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Maximum Production Equipment Pressure Required (psig)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat Plant</td>
<td>80</td>
</tr>
<tr>
<td>Dairy</td>
<td>100</td>
</tr>
<tr>
<td>Beverage Plant</td>
<td>100</td>
</tr>
<tr>
<td>Bakery</td>
<td>25-50</td>
</tr>
</tbody>
</table>
Steam Pressure Reduction (continued)

- Allow 10 psi distribution loss and 5 psi non-return valve pressure drop.

- Optimum meat plant design pressure is 100 psig which includes a 5% safety factor.

- Reducing pressure in an existing plant from 120 psig to 100 psig results in an energy savings of 0.02 x $1,600,000 or $32,000/year.
Turndown

- Model plant operates at 105 hp or 21% (105 hp/500 hp) on weekends. Turndown of 5/1 can be selected vs. 4/1 at little or no extra 1\textsuperscript{st} cost.
- Similar plant with three 700 hp boilers with same steam loads would operate at 15% (105 hp/700 hp) on weekends indicating a desirable turndown of 7/1 or 8/1, annual fuel cost of $2,800,000.
- 8/1 turndown increased first cost of $17,200 per boiler with manufacturer indicated energy savings of 0.75% in energy. Payback would be $17,200 x 3 boilers/(0.0075 x $2,800,000) = 2.5 years.
Economizer Types

Single Stage

- Nominal 3% increase in boiler efficiency
- Energy savings = $48,000/year
- First costs including feedwater piping: $63,000
- Payback: 2 x 
  $63,000/$48,000 = 2.6 years
Economizer Types (continued)

Two-Stage Stack (Condensing)

- 1\textsuperscript{st} stage extract sensible heat to heat boiler feedwater
- 2\textsuperscript{nd} stage extract remaining sensible heat and latent heat to preheat other plant users of hot water
- Up to 10% savings in boiler efficiency
- Energy savings: $160,000/\text{year}$
- Estimated first costs including feedwater piping, hot water piping, storage tank(s) and pumps: $215,000$
- Payback: $215,000 \times 2 / $160,000 = 2.7 \text{ years}$
Economizer Types (continued)

Free Standing – Direct Contact and Indirect Contact

- Direct contact suitable for smaller plants
- Indirect contact suitable for 150,000 lb./hour and larger plants
- Direct contact—up to 10% savings in boiler efficiency
- Energy Savings: $160,000/year
- Estimated first cost for 1000 hp inclusive of hot water storage tanks, piping, pumps, and stack = $440,000
- Payback: $440,000/$160,000 = 2.8 years
Blowdown Heat Recovery

- Continuous surface blowdown to remove TDS
- At 100 psig TDS maximum recommended concentration = 3500 ppm
- Automatic surface blowdown measuring conductivity is recommended
- 90% of heat in blowdown is recoverable as flash steam and for preheating boiler make-up water.
- Model blowdown rate = 11.4%
- Energy savings: $185,000/year
- Estimated first cost including piping: $83,000
- Payback: $83,000/$185,000 = 0.5 year
Reverse Osmosis (RO)

- Softening of boiler make-up water does not reduce TDS
- Make-up water @ 400 ppm TDS
- Blowdown rate – 11.4%
- RO systems reduces TDS by 85% & blowdown rate to 2%
- Energy cost at 11.4% blowdown: $182,000/year
- Energy cost at 2% blowdown: $32,000/year
- Energy savings: $150,000/year
Reverse Osmosis (continued)

- Estimated first cost including softener, carbon filter, anti-scalant unit, storage tank and repressure pumps: $255,000
- Payback: $255,000/$150,000 = 1.7 years
Oxygen Trim

- Gas-fired firetube boilers without O₂ trim normally tuned for 15% excess air (3% O₂ in combustion products)
- With O₂ trim, 10% excess air is attainable (2% O₂ in combustion products)
- O₂ trim controls excess air at 2% O₂ as load varies
- O₂ trim provides energy savings of 1% to 2%
- Energy savings at 1%: $16,000/year
- Estimated first cost per boiler: $19,600
- Payback: (2 x $19,600)/$16,000/year = 2.5 years
Conclusions

- Consider the options on a case-by-case basis.
- Payback can be highly attractive: Remember that annual fuel costs far exceed boiler plant first costs.
- Always obtain an analysis of the water source employed for boiler make-up.
- Consider availability and capability of operating staff.
- Include additional space requirements where considering free-standing economizers and RO make-up water treatment.