Performance & Benchmarking of Steam Systems
In the Indian Process Industries

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Forbes Marshall

Introduction

• The great need, the great interest, and the great potential for energy savings
• We are moving from conservation as a fashion statement to reality
  – Helped greatly by huge volatility in fuel prices
  – Potential for savings in process steam alone is over Rs 8,000 Crores
• But reality does not match potential
  – Diagnosing the problem – Time to get specific
  – Priorities in Energy Conservation - some thoughts from Steam systems
  – Making Conservation happen – from an audit to implementation to sustained savings
Our perspective

• That of a practitioner, coming from a firm that specialises in energy conservation
• Our focus is micro - it is bottom-up, from how firms act
• Our knowledge base is steam systems - but our (not my!) knowledge base is solid
  – Our estimate of Rs 8,000 Crores in potential process steam savings comes from
    • Three rounds of Forbes Marshall - CII Study of hundreds of plants
    • Thousands of detailed plant surveys over 60 years
    • Hundreds of detailed Energy Audits & Utility Consultancy projects
• We believe we can extract insight on what it takes to make energy conservation really happen (from fashion statement to reality) from all this micro case data

An efficient Steam & Condensate Loop

100% fuel energy → 80% steam → 3% distribution losses → 77% Process consumption 57% → Condensate & Flash 20% → Unburnt Stack Blowdown
Case 1: How efficient is the Boiler?
Direct, Indirect, Ideal efficiency

- Ideal Steam: Fuel ratio for Oil & Gas, 14.5 - 15
  - Actual is 12
  - (And if it is a coil-type boiler, then 6 - 7)

- Ideal for Solid-fuel (wood, husk), 3.5 - 4
  - Actual is 2.5 - 2.8

- Why the huge difference?
  - 3/4ths of gap in solid fuel & 1/2 in liquid is the difference between Direct and Indirect efficiency
    - Feed Water Temperature
    - Over-sized boilers
      - Stop-start operations
      - Part-load operations
    - Combustion regulation - > 2/3rd gain from manual adjustments

Perception and Reality
Ideal, Indirect & Direct Efficiency (Avg)
Coil and Smoke Tube Boilers

- Common knowledge that Coil boilers are used by industry *only* to avoid IBR regulations - which we were to change but didn’t!. But how bad are they?
- Claim is bad enough - 85% dry steam. Our experiments show that 65% is the best dryness fraction possible to attain, with pressure and load held constant. The average is 50% (coil = geyser)
- We have a hundred cases around the country with savings of 25%+ in diesel to diesel conversions
- The savings would have been more if the boiler had been correctly sized - we are generally running at below 50% of boiler capacity
- And this says nothing about the improvements in batch timings and process from the dry steam

**Coil vs. Shell**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before (Coil Boiler)</th>
<th>After (3 pass wet back Smoke tube Shell Boiler)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler Capacity</td>
<td>400 kg/hr x 2, 600 kg/hr x 1</td>
<td>1100 kg/hr x 1</td>
</tr>
<tr>
<td>Fuel</td>
<td>Furnace Oil</td>
<td>Furnace Oil</td>
</tr>
<tr>
<td>Boiler Efficiency</td>
<td>66 %</td>
<td>84 %</td>
</tr>
<tr>
<td>Dryness Fraction</td>
<td>60 %</td>
<td>98 %</td>
</tr>
<tr>
<td>Steam : Fuel Ratio</td>
<td>9.3 : 1</td>
<td>14.0 : 1</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>25,000 Litres / month</td>
<td>13,000 Litres / month</td>
</tr>
</tbody>
</table>

Production (For batch of 100 ml)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before (Coil Boiler)</th>
<th>After (3 pass wet back Smoke tube Shell Boiler)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO Consumption</td>
<td>800 Litres / day</td>
<td>450 Litres/ day</td>
</tr>
<tr>
<td>Heating Time</td>
<td>55 minutes</td>
<td>40 minutes</td>
</tr>
</tbody>
</table>
Case 2:
How much condensate is being returned?

- What is the right Condensate Recovery Factor?
  - Generally the answer is 60 - 70%
  - It should be 97% of Indirect Steam Consumption in a well-engineered steam system

- What is it actually?
  - A study we did three years ago: less than half of the 90 plants we studied returned > half of their recoverable condensate
  - Breweries
    - We audited six in the last year, to find CRF of 33 - 74%.
    - The projected CRF is 72 - 76%
    - We designed the steam system for a brewery in Hyderabad, which gets 95% (and it should be 98%)
  - Refineries
    - Actual of four audited in last quarter, 17 - 65%
    - Projected is 50 - 82% (and remember 5%+ = 40 tph!)
  - Chemicals
    - Actual of ten chemical plants audited, 25 - 80%
    - Projected is 60 - 98%

- 90%+ CRF must be our target

Condensate Recovery – Perception & Reality

<table>
<thead>
<tr>
<th>Industry</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP</td>
<td>Improper design of system</td>
</tr>
<tr>
<td>Textile</td>
<td>Plant Layout, CRS+FS design</td>
</tr>
<tr>
<td>Paper</td>
<td>Flash recovery w/o affecting trap performance</td>
</tr>
<tr>
<td>Brewery</td>
<td>Bottle washer condensate recovery</td>
</tr>
<tr>
<td>Beverage</td>
<td>Sustaining CRF</td>
</tr>
<tr>
<td>Tyre</td>
<td>Flash Steam Loss highest. Water - mass &amp; energy balance</td>
</tr>
<tr>
<td>Pharma &amp; Chem</td>
<td>Contamination of condensate due to Multiple Utility cycles</td>
</tr>
</tbody>
</table>
Case 3: How many “leaking” process traps?

- In 12 recently audited Pharmaceutical plants
  - 45% of process traps were Thermodynamic
    - Close to 65% had bypasses open (= leaking)
  - 47% were Float
    - 8% were blocked so bypasses open again (= leaking)
- And remember that for every X unit of energy leaked through the trap, 1.75 X energy is consumed in the boiler (1/0.57)
- Our findings show that between 30% and 70% of process steam traps are wrong in some way - selection, maintenance, operation
- On-line monitoring of steam traps is the only way to sustain a good process

### Process Traps – Actual Findings

<table>
<thead>
<tr>
<th>Industry</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP</td>
<td>Trap Selection &amp; design of CRS</td>
</tr>
<tr>
<td>Textile</td>
<td>Trap Selection - group trapping issues</td>
</tr>
<tr>
<td>Paper</td>
<td>System design; Operating practices.</td>
</tr>
<tr>
<td>Brewery</td>
<td>Bottle washer stalling of traps</td>
</tr>
<tr>
<td>Pharma</td>
<td>Selection of traps; Multiple Utility</td>
</tr>
<tr>
<td>Chemical</td>
<td>Balance not known</td>
</tr>
<tr>
<td>Refineries</td>
<td>27% failed + no trap locations</td>
</tr>
</tbody>
</table>
Learnings from these mundane areas of boiler efficiency, condensate recovery, and steam traps

• Much more is possible to achieve in energy conservation - there are huge opportunities. 20%+ in energy savings between these three areas

• Ensure perceptions match reality - get the hard data on actual operations on a continuous real-time basis - diagnosis is critical

• See investment in equipment as step 1 - and only step 1 (Buying a high efficiency boiler • high efficiency)

• The operation and maintenance of the equipment is even more important

The Mundane gives Big savings

<table>
<thead>
<tr>
<th>Plants # / Specific fuel consumption</th>
<th>Routine Plants</th>
<th>Plants with correct Process Trapping and Condensate Recovery</th>
<th>Plants with correct Process Trapping, Condensate Recovery, Flash Recovery &amp; on-line diagnosis &amp; Boiler Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Bran Kg Husk/ton</td>
<td>142</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Soya Kg Husk/ton</td>
<td>88</td>
<td>66</td>
<td>47</td>
</tr>
</tbody>
</table>
Getting specific about conservation potential

• We have long claimed that the average well-managed plant in the country can save 10 – 25% of its steam fuel bill – but that was only a claim!

• Decided we had better get at the facts:
  – For CII 2003, we studied 97 firms in Textiles, Paper, Tyres, Breweries, Pharmaceuticals and Hotels
  – The savings potential for steam ranges from 22% to 64%
  – Second and Third rounds in 2005 and 2007

• Tyres 22%, Breweries 25%, Paper 44%, Textiles 54% and Hotels 64%
  – These are not academic figures from theory or comparing some plant in Japan
  – These compare the average with the best firm down the road – operating under the same conditions, with the same fuel, with the same raw materials

Our Benchmarking findings of Specific Fuel Consumption

<table>
<thead>
<tr>
<th>Industry</th>
<th>Units</th>
<th>Best</th>
<th>Average</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewery</td>
<td>FO Lit/KL Beer</td>
<td>44</td>
<td>58</td>
<td>75</td>
</tr>
<tr>
<td>Tyre</td>
<td>FO Kg/Ton Finished Tyre</td>
<td>162</td>
<td>210</td>
<td>353</td>
</tr>
<tr>
<td>Textile</td>
<td>Firewood Kg/ Kg</td>
<td>1.57</td>
<td>2.75</td>
<td>5.12</td>
</tr>
<tr>
<td>SEP Soya</td>
<td>Coal Ton / Ton Seed Crushed</td>
<td>47</td>
<td>70</td>
<td>93</td>
</tr>
<tr>
<td>SEP Rice Bran</td>
<td>Husk Ton / Ton Seed Crushed</td>
<td>100</td>
<td>115</td>
<td>124</td>
</tr>
<tr>
<td>Beverage</td>
<td>KL Beverage / KL Fuel (FO)</td>
<td>189</td>
<td>107</td>
<td>76</td>
</tr>
<tr>
<td>Paper*</td>
<td>Ton Steam/Ton Paper</td>
<td>1.5</td>
<td>1.9</td>
<td>3</td>
</tr>
<tr>
<td>Coil Type Boilers</td>
<td>Steam: Fuel Ratio</td>
<td>10</td>
<td>7.5</td>
<td>6</td>
</tr>
<tr>
<td>Smoke Tube Boilers</td>
<td>Steam: Fuel Ratio</td>
<td>15</td>
<td>12.5</td>
<td>10</td>
</tr>
</tbody>
</table>
The Average is improving

- Brewery: 58 has improved to 50 litres/KL
  - 10 m litres of FO/yr = Rs 16 Cr
- Paper: 1.9 kg/kg to 1.8 kg/kg
  - 15,000 tonnes of rice husk = Rs 5 Cr
- Tirupur Textiles: 2.8 kg wood/kg cloth to 2.3 kg wood/kg of cloth
  - 35,000 tonnes of wood = Rs 7 Cr

And we are making the best better

- A Brewery in Hyderabad
  - Committed 42 L of FO per KL of Brew (which was the best in our study)
  - Existing brewery was at 55 L/KL
  - We did the detailed engineering of the steam system to ensure 95% Condensate Recovery
  - The brewery achieved 36 – 38 L/KL, but has since fallen back
- A Solvent plant in MP
  - Existing plant was 57 (kg of coal per tonne of seeds crushed)
  - The industry best was 50
  - We did the detailed engineering to monitor boilers on line, to return 95% of recoverable condensate, to use flash steam, and with correct process traps
  - The plant is achieving 43 - 46
- So best is not best, and perhaps we can achieve an extra 10% of savings over the 24% gap of average to “best”
Creating New Benchmarks of Specific Fuel Consumption

<table>
<thead>
<tr>
<th>Industry</th>
<th>Units</th>
<th>Improved / 2005 Best</th>
<th>Improved / 2005 Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewery</td>
<td>FO Lit/KL Beer</td>
<td>36 / 44</td>
<td>&lt;50 / 58</td>
</tr>
<tr>
<td>Tyre</td>
<td>FO Kg/Ton Finished Tyre</td>
<td>140 / 162</td>
<td>190 / 210</td>
</tr>
<tr>
<td>Textile</td>
<td>Firewood Kg/ Kg</td>
<td>1.46 / 1.57</td>
<td>2.26 / 2.75</td>
</tr>
<tr>
<td>SEP Soya</td>
<td>Coal Ton / Ton Seed Crushed</td>
<td>47</td>
<td>58 / 70</td>
</tr>
<tr>
<td>SEP Rice Bran</td>
<td>Husk Ton / Ton Seed Crushed</td>
<td>61 / 100</td>
<td>111 / 115</td>
</tr>
<tr>
<td>Paper</td>
<td>Ton Steam/Ton Paper</td>
<td>1.4 / 1.5</td>
<td>&lt;1.7 / 1.9</td>
</tr>
</tbody>
</table>

* The best in Soya that we designed continues to remain the best

Understanding SFC

Improvement in SFC is made up of two components – S:F and SSC

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total Savings</th>
<th>S:F</th>
<th>SSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP</td>
<td>28%</td>
<td>5%</td>
<td>23%</td>
</tr>
<tr>
<td>Brewery</td>
<td>30%</td>
<td>11%</td>
<td>19%</td>
</tr>
<tr>
<td>Tyre</td>
<td>35%</td>
<td>6%</td>
<td>29%</td>
</tr>
<tr>
<td>Textile</td>
<td>26%</td>
<td>10%</td>
<td>16%</td>
</tr>
<tr>
<td>Pharma &amp; Chem</td>
<td>32%</td>
<td>17%</td>
<td>15%</td>
</tr>
<tr>
<td>Paper</td>
<td>26%</td>
<td>6%</td>
<td>20%</td>
</tr>
<tr>
<td>C2S</td>
<td>45%</td>
<td>15%</td>
<td>30%</td>
</tr>
</tbody>
</table>
Factors Impacting S:F

Solid Fuel Boilers
- Feedwater temp & Management – increased condensate & flash steam recovery
- Fuel characteristics – Moisture & Ash content
- Type of boiler & the fuel feeding mechanism
- Operating practices – Diagnostics & Monitoring

Oil/Gas Fired Boilers
- Feedwater temp & Management – increased condensate & flash steam recovery
- Boiler Loading – On/off cycles and Stand By
- Burner & Boiler package settings
- Manual operations, including parameters like – TDS & Excess air

Factors Impacting SSC

<table>
<thead>
<tr>
<th>Process Equipment</th>
<th>Steam leakages</th>
<th>Steam Distribution</th>
<th>Waste heat recovery</th>
<th>Capacity Utilization</th>
<th>Process Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP</td>
<td>1%</td>
<td>7%</td>
<td>5%</td>
<td>8%</td>
<td>-</td>
</tr>
<tr>
<td>Brewery</td>
<td>3%</td>
<td>3%</td>
<td>✓</td>
<td>13%</td>
<td>✓</td>
</tr>
<tr>
<td>Tyre</td>
<td>13%</td>
<td>✓</td>
<td>16%</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Textile</td>
<td>5%</td>
<td>1%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pharma &amp; Chem</td>
<td>7%</td>
<td>5%</td>
<td>✓</td>
<td>2%</td>
<td>-</td>
</tr>
<tr>
<td>Paper</td>
<td>14%</td>
<td>3%</td>
<td>✓</td>
<td>✓</td>
<td>?</td>
</tr>
</tbody>
</table>
Steam System Management – F&B

- Improvement in S:F from 2 to 3.5
- The f/w temperature improved from 25 to 95°C
- Successful Zero leak program

Steam System Management – SEP

• Improvement in SPFC from 127.4 to 110.98kg/MT, Target 75kg/MT

• S:F improved from 2.6 to 3.1 via boiler tuning and correct operating practices

• SSC improved from 351.7 kg steam/MT rice bran to 344.5kg steam/MT rice bran on account of Zero Leakages from line flange/valves, traps loss elimination by repairs/replacement & improved quality of steam on account of working line traps.
Steam System Management – SEP

Making savings happen

- Diagnosis of the problem - our SFC work provides specific understanding of what savings are possible
- Investment in the right technology: old and new
- Energy conservation as a Management Issue: who is accountable for energy consumption?
- Priorities in Energy Conservation
Making Conservation happen: managing implementation

• Need an effective management structure
  – Committed top management to drive savings
  – Imaginative process and plant engineers and managers to propose the right schemes
  – Effective maintenance technicians to sustain savings

• Permanent Savings:
  – Audits for Diagnosis as step one
  – Implementation as step two - and focus on savings, not just working products
  – The hard work of day-to-day perfect operation

As the leading Energy Conservation supplier, what should our target for energy conservation be?

• The 90 firms we studied are quite typical – they can save 80 Crores in process steam annually
• So for 10,000 steam users, we can expect a minimum saving of Rs 8000 Crores annually
• That is without the giant refinery and fertilizer plant savings possible
(As a firm, we are targeting 10% of that 8000 Cr by way of annual business by 2010 – so we have 3x growth to go after)
Priorities in Energy Conservation

Start with the small things, then move to the bigger

# 1: Housekeeping - fix leaks and insulation. Potential: 2 to 5% with negligible investment

# 2: Many small things - payback around 6 months
  - Process traps - save 10%+
  - Condensate and Flash Steam recovery - save 8 to 15%
  - Temperature controls - save 2 to 10%

# 3: Diagnosis - metering steam, condensate, efficiency

# 4: Capital investment - new boilers, cogen, process automation

Conclusion

Half full
• Greatly improved standards - you just see much less of steam leakages in a well-managed plant
• Focus and priority as never before
• A willingness to invest as never before
• Our data permits us to be much more specific and credible in conveying our message

Half empty
• Often the perception one is doing fine (fashion statement), when one isn’t (reality)
• The big gaps that still exist between potential and reality

The time has never been better for sustained interest in energy savings - 8000 Cr annual savings is a great opportunity for us to achieve together
Conclusion

The time has never been better for sustained interest in energy savings - 8000 Cr annual savings is a great opportunity for us to achieve together.