Results from 18 Field Monitoring Projects on Rack and Flight Conveyor Dishwashers
Restaurants are an Energy and Water Intensive Operation

Responsible for up to 75% of the hot water utility costs.
Heavy Dishwasher Use in FSR

- Hot Water Flow
- Dishwasher Flow
- Total Hot Water
- Total Dishwasher

3630 gal used by dishwasher

570 gal used from 8 AM to 10 PM

Closed at 9:30 PM, 370 gal used for after hours cleanup
Why the scrutiny on dishwashers?

• Theorized that retrofitting to efficient dishwashers would be straightforward, guaranteeing long-term savings like other equipment in commercial kitchens
  – True with smaller batch-style washers
  – False with conveyor dishwashers

• Set out to submeter dishwashers in the field to measure savings potential

• Realized that conveyor dishwashers are pretty complex machines with lots of failure points

• Payback period was good, but there was a problem, how do we guarantee the savings through the working life of the new equipment?
Research focus areas

• Quantify energy and water use of existing baseline dishwashers and replacement high-efficiency machines installed in the field
• Develop some parameters of baseline equipment to normalize comparison
  – Hours per day of rinse use, conveyor use and daily operating span
  – Normalize to gal/h, therms/h, and kWh/h of rinse operation
• Compare actual water and energy use versus specifications
• Investigate water and energy use profiles to figure out what is normal operation and what is a malfunction
• What goes wrong with old machines and why?
• Verification on if dishwashers hold their specification?
Monitoring of Rack Conveyors

Trends

• Most units were found in poor condition.
• Shocking water use for tank fill operation

Dishwasher Projects

• 6 in Hotels
• 9 School and Commercial Cafeterias
• 3 Full Service Restaurants
Original Dishwasher in University Kitchen

• Steamy room even with 3 fans going
• Large amount of water and energy use due to old steam distribution system, dishwasher, table layout
New Dishwasher w/ Heat Recovery

- Significantly more comfortable work environment
  - Removal of steam system
  - Insulated doors
  - Door seal system
- Door actuated drain closure
- Vent fan control
- Energy saver mode
- Built-in booster heater
- Final rinse flow rate specification of 2.2 gpm
# Preliminary Results From Rack Conveyor Replacement Project

<table>
<thead>
<tr>
<th></th>
<th>Water Use (gal/d)</th>
<th>Electricity Use (kWh/d)</th>
<th>Gas Use (therms/d)</th>
<th>Utility Cost ($/d)</th>
<th>Total Energy Use (therms/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original 108” Rack</td>
<td>1372</td>
<td>21</td>
<td>30.2</td>
<td>$57</td>
<td>31.0</td>
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<tr>
<td>Conveyor Dishwasher</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Replacement 86” Rack</td>
<td>628</td>
<td>276</td>
<td>3.2</td>
<td>$52</td>
<td>12.6</td>
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<tr>
<td>Conveyor Dishwasher</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Savings Percentage</td>
<td>54%</td>
<td>-92%</td>
<td>89%</td>
<td>9%</td>
<td>59%</td>
</tr>
<tr>
<td>Fuel Switching and low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hot water supply temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of 120°F responsible</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>for low cost savings</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Original Dishwasher in Work Cafeteria

- 98 gph spec. rinse flow rate
- 189 gph measured rinse flow rate
- The high flow rate and high drain temperatures where causing campus drain pumps to seize up
- Using 2 million gallons of water annually
New Dishwasher w/ Heat Recovery + Blower Dryer

- 58 gph spec. rinse flow rate
- 71 gph measured rinse flow rate
- More comfortable work environment
  - Insulated doors
  - Door seal system
- Vent fan control
- Energy saver mode
## Final Results From Flight Dishwasher Replacement Project

<table>
<thead>
<tr>
<th></th>
<th>Water Use (gal/d)</th>
<th>Electricity Use (kWh/d)</th>
<th>Gas Use (therms/d)</th>
<th>Utility Cost ($/d)</th>
<th>Total Energy Use (therms/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original Flight Conveyor Dishwasher</strong></td>
<td>5656</td>
<td>668</td>
<td>48.0</td>
<td>$271</td>
<td>70.8</td>
</tr>
<tr>
<td><strong>Replacement Flight Conveyor w/ Heat Recovery + Blower Dryer</strong></td>
<td>1857</td>
<td>931</td>
<td>10.0</td>
<td>$240</td>
<td>41.8</td>
</tr>
<tr>
<td><strong>Savings Percentage</strong></td>
<td>67%</td>
<td>-39%</td>
<td>79%</td>
<td>11%</td>
<td>41%</td>
</tr>
</tbody>
</table>

The addition of a blower dryer on the replacement unit increased overall electricity use.
Commissioning of Dishwashers with Heat Recovery

- Marketing materials of dishwashers with exhaust-air heat recovery imply or state that only cold water is used through the heat exchanger to preheat water used by the booster heater.

- This is true of the flight conveyors tested, but not the rack conveyors.
Commissioning of Two High-Efficiency Unit with Heat Recovery

- As commissioned by the manufacturer’s technicians at two sites
- Hot water and cold water used during the rinse cycle at a 2 to 1 ratio
- Heat Recovery device is not performing, **booster efficiency w/ HX of 87%**
Commissioning of Two High-Efficiency Unit with Heat Recovery

- **Recommissioned at one site**, flow profile has completely changed
- Heat Recovery now performing, **booster efficiency w/ HX of 102%**
- **Savings of $900 per year**

Start of rinse uses more hot water

Switches to mostly cold water
Results from 18 Conveyor Dishwasher Monitoring Projects

• Metrics Development: What’s the best parameters to use for comparison of dishwashers?

Answer: Normalized all data to consumption per hour of rinse operation

• Theoretical dishwasher water use versus actual water use.

• Savings comparison of conventional vs. high-efficiency dishwashers.

• Sizing dishwasher considerations
Model specifications vs. actual water use for rack-conveyor dishwashers

<table>
<thead>
<tr>
<th>Dishwasher Make and Model</th>
<th>Specified Rinse Flow Rate (gph)</th>
<th>Actual Rinse Flow Rate (gph)</th>
<th>Theoretical Rinse and Fill (gph)</th>
<th>Machine Water Use Per Hour Rinse Operation (gph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Low-Temp 44”</td>
<td>315</td>
<td>244</td>
<td>328</td>
<td>730</td>
</tr>
<tr>
<td>Old High-Temp 44”</td>
<td>290</td>
<td>524</td>
<td>303</td>
<td>542</td>
</tr>
<tr>
<td>Old High-Temp 44”</td>
<td>223</td>
<td>215</td>
<td>236</td>
<td>235</td>
</tr>
<tr>
<td>Old High-Temp 44”</td>
<td>290</td>
<td>288</td>
<td>303</td>
<td>363</td>
</tr>
<tr>
<td>Old High-Temp 66”</td>
<td>290</td>
<td>328</td>
<td>311</td>
<td>389</td>
</tr>
<tr>
<td>Old High-Temp 66”</td>
<td>290</td>
<td>221</td>
<td>311</td>
<td>416</td>
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<tr>
<td>Old High-Temp 86”</td>
<td>226</td>
<td>289</td>
<td>259</td>
<td>2194</td>
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<tr>
<td>Old High-Temp 108”</td>
<td>309</td>
<td>319</td>
<td>311</td>
<td>667</td>
</tr>
<tr>
<td>Efficient High-Temp 66”</td>
<td>78</td>
<td>89</td>
<td>111</td>
<td>135</td>
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<tr>
<td>Efficient High-Temp 64”</td>
<td>132</td>
<td>172</td>
<td>161</td>
<td>367</td>
</tr>
<tr>
<td>Efficient HT 86” + HR</td>
<td>132</td>
<td>147</td>
<td>176</td>
<td>261</td>
</tr>
<tr>
<td>Efficient HT 86” + HR</td>
<td>132</td>
<td>152</td>
<td>176</td>
<td>301</td>
</tr>
<tr>
<td>AVG. Conventional Conveyor</td>
<td>274</td>
<td>304 (11% ↑)</td>
<td>295</td>
<td>692 (134% ↑)</td>
</tr>
<tr>
<td>AVG. High-Efficiency Conveyor</td>
<td>119</td>
<td>140 (18% ↑)</td>
<td>156</td>
<td>266 (70% ↑)</td>
</tr>
</tbody>
</table>
Model specifications vs. actual water use for flight-conveyor dishwashers

<table>
<thead>
<tr>
<th>Dishwasher Make and Model</th>
<th>Specified Rinse Flow Rate (gph)</th>
<th>Actual Rinse Flow Rate (gph)</th>
<th>Theoretical Rinse and Fill (gph)</th>
<th>Machine Water Use Per Hour Rinse Operation (gph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old High-Temp Flight</td>
<td>336</td>
<td>372</td>
<td>420</td>
<td>605</td>
</tr>
<tr>
<td>Old High-Temp Flight</td>
<td>336</td>
<td>357</td>
<td>420</td>
<td>1277</td>
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<tr>
<td>Old High-Temp Flight</td>
<td>336</td>
<td>516</td>
<td>183</td>
<td>1770</td>
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<tr>
<td>Old High-Temp Flight</td>
<td>98</td>
<td>189</td>
<td>163</td>
<td>823</td>
</tr>
<tr>
<td>Efficient High-Temp Flight</td>
<td>58</td>
<td>71</td>
<td>145</td>
<td>232</td>
</tr>
<tr>
<td>Efficient High-Temp Flight</td>
<td>58</td>
<td>63</td>
<td>145</td>
<td>303</td>
</tr>
<tr>
<td>AVG. Conventional Conveyor</td>
<td>277</td>
<td>359 (30% ↑)</td>
<td>361</td>
<td>1119 (210% ↑)</td>
</tr>
<tr>
<td>AVG. High-Efficiency Conveyor</td>
<td>58</td>
<td>67 (15% ↑)</td>
<td>145</td>
<td>267 (84% ↑)</td>
</tr>
</tbody>
</table>

Based on rated rinse and tank volume specs:
- Old dishwashers consume 2-3 times more water than predicted
- HE dishwashers consume 70% to 85% more water than predicted
AVG. Results From Monitoring 18 Conveyors

• Efficient rack conveyor dishwashers on average used 60% less water and 65% less energy than conventional units

Old: 690 gal/h
1,500,000 Btu/h

New: 260 gal/h
530,000 Btu/h

• Efficient flight conveyor dishwashers on average used 75% less water and 55% less energy than conventional units

Old: 1120 gal/h
1,430,000 Btu/h

New: 270 gal/h
650,000 Btu/h
Rinse Flow Rate Should No Longer be the Default Efficiency Parameter

- Rated rinse flow rate accounted for 25%-50% of total use
- Rinse flow rate alone cannot reasonably predict the water and energy consumption in the field
- Incentive and recognition programs (ENERGY STAR®, LEED) need to take a more comprehensive approach

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Specified Rinse Flow Rate (gph)</th>
<th>Water Use Per Hour of Rinse Operation (gph)</th>
<th>Rinse Divided by Real World Water Use</th>
<th>Data Range (Rinse/Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Rack Conveyor</td>
<td>274</td>
<td>692</td>
<td>40%</td>
<td>10% - 95%</td>
</tr>
<tr>
<td>High-Efficiency Rack Conveyor</td>
<td>119</td>
<td>261</td>
<td>46%</td>
<td>36% - 58%</td>
</tr>
<tr>
<td>Conventional Flight Conveyor</td>
<td>277</td>
<td>1119</td>
<td>25%</td>
<td>12% - 56%</td>
</tr>
<tr>
<td>High-Efficiency Flight Conveyor</td>
<td>58</td>
<td>267</td>
<td>22%</td>
<td>19% - 25%</td>
</tr>
</tbody>
</table>
Benchmarking: Number of Meals

Energy use per meal per day ranges from:
- 700-2,400 Btu/h (old units)
- 400-1,000 Btu/h (new units)

Water use per meal per day ranges from:
- 0.5-1 gal (old units)
- 0.2-0.5 gal (new units)
Benchmarking: Number of Seats

Energy use per seat per day ranges from:
- 4,500-8,000 Btu/h (old units)
- 2,000-4,500 Btu/h (new units)

Water use per seat per day ranges from:
- 2-6 gal (old units)
- 1-2 gal (new units)
Energy use per 1000 ft² per day ranges from:

- 150-250 kBtu/h (old units)
- 50-150 kBtu/h (new units)

Water use per 1000 ft² per day ranges from:

- 60-200 gal (old units)
- 30-65 gal (new units)
Sizing for Hot Water Demand with Conveyors

Existing health department sizing guidelines

Current water heater sizing procedure involves looking up water use information from NSF listings or spec sheets for:

- Final rinse flow rate (gpm) for sizing tankless
- Maximum hourly rinse use (gph) for sizing storage heaters
- On this particular flight unit, the tank fill water use at 127 gallons is twice that of the final rinse at 58 gallons

<table>
<thead>
<tr>
<th>Machine Ratings (Mechanical)</th>
<th>FT1000 Base Series (5.5, 7.5, 9 Load / 8 Center / 5.5, 7.5, 9 Unload)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyor Speed — Feet per minute</td>
<td>4.0 - 8.5</td>
</tr>
<tr>
<td>Dishes per Hour</td>
<td>14,316</td>
</tr>
<tr>
<td>Motor — Horsepower</td>
<td>Pre-Wash - 3½; Wash - 5; Rinse - 5; Dual Rinse - ½; Final Rinse - ½; Conveyor - ½</td>
</tr>
<tr>
<td>Tank Capacity — Gallons</td>
<td>Pre-Wash - 40; Wash - 40; Rinse - 40; Dual Rinse - 7.2</td>
</tr>
<tr>
<td>Rate of Final Rinse — Gallons per minute (Pumped rinse)</td>
<td>.97</td>
</tr>
<tr>
<td>Final Rinse Consumption — Gallons per hour (Pumped rinse)</td>
<td>58</td>
</tr>
</tbody>
</table>
Hot Water Demand Rated vs. Measured

Rated rinse versus measured maximum hot water use

Monitored maximum use is 300 gal/h

Spec. Rinse is 58 gal/h

241% Increase

397% Increase
Conveyor Dishwasher Hot Water Demand

Reasons for the disparity

• Overspray from washing large back of the house wares, especially flat wares such as sheet pans and cutting boards was the leading factor

• Leaving the tank drain open was the second leading cause

• Dishwasher components fail and maintenance is not completed
Operations Causing Overspray

Water Overspray on 66” Conveyor = 540 gal/d of water waste
Operations Causing Overspray

Water Overspray of Old 44” Unit =
1170 gal/d of water waste

Useful Rinse and Tank Fill =
595 gal/d of water waste
Check Operations: Look for Operator Error

Manual Override = 1740 gal/d of water waste
Hot Water Demand Sizing Recommendations

• Need to change sizing guidelines to incorporate tank fill operation

• If the facility is washing back of the house wares, a water waste factor may be added

• Can use specialty racks like sheet pan racks with many rack conveyors
Summary of Sanitation Room Research

Water and energy savings is only achievable in the sanitation room through a combination of practices:

• Specify properly sized and efficient dishwashers and pre-rinse equipment
• Properly commission equipment to include sub-metering to measuring baseline use
• Training program for staff
• Maintenance program
Or we can Maintain the Status Quo
Thanks for Listening!

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