This presentation premiered at WaterSmart Innovations

watersmartinnovations.com
Results of 22 Monitoring Projects on Conveyor Dishwashers in Commercial Kitchens

Brought to you by:

Food Service Technology Center
PG&E

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Research/Project Engineer

Food Service Technology Center

fishnick.com

FRONTIER energy
The Food Service Technology Center (FSTC) is an unbiased energy-efficiency research program funded by California utility customers.
Energy Audits
Appliance Testing
Seminars
Facility Design
Energy Audits
Conveyor Dishwasher Summary Reports

Original report funded by: PG&E and Metropolitan Water District under the Innovative Conservation Program in 2015

- Covers 9 dishwasher case studies
- Summarizes 9 previously monitored sites

http://bewaterwise.com/ICP_projects.shtml

ASHRAE Conference Paper in 2017

- Adds 2 new case studies
- Covers prior 18 sites
- Refines the findings from all sites

www.techstreet.com/searches/17148009
Recent Publications

Rack Conveyor Design Guide

- Focus on water, energy and chemical savings
- Information is relevant to other types of dishwashers

https://fishnick.com/design/dishwashers/

ET Coordinating Council Paper

- Funded by PG&E
- Monitoring at SFO catering site
- Compares best-available technologies with flight conveyors

http://www.etcc-ca.com/reports/energy-efficient-flight-conveyor-dishwashers
Learning Objectives

- Distinguish between rack and flight type conveyors in the field and be able to characterize the machine's efficiency level
- Recognize that the rated rinse flow rate is not a good metric for gauging the “real world” water and energy use
- Understand the distortions in the marketplace that make it difficult for an operator to see clearly between models and choose the best conveyor model
- Develop a solid incentive programs that promotes best-in-class dishwashers over business-as-usual efficiency upgrade
Why the Research

- Based on preliminary studies, old rack conveyor dishwasher can account for up to 80% of the total hot water use.
- Set out to sub-meter dishwashers in the field to measure savings potential.
- Rapid advances in technologies being marketed in last 5 years, high savings potential.
- What technologies work?
- Will it save over its useful life?
- Which technologies are marketing hype?
- First-of-its kind research.
Sites and Condition of Dishwashers

Observations
- Most units were found in poor condition
- Shocking water use for tank filling and top off operations

Dishwasher Projects
- 7 Hotels, 3 Restaurants
- 10 School, Commercial, Army Cafeterias
- 2 Airline Catering Facility
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 were causing wastewater pumps to seize up
- The unit used over 2 million gallons/y
New Unit 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
# Results From Flight Dishwasher Replacement

<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 Flight Conveyor Dishwasher</td>
<td>5656</td>
<td>668</td>
<td>48.0</td>
<td>$271</td>
<td>70.8</td>
</tr>
<tr>
<td>Replacement Flight Conveyor w/ Heat Recovery + Blower Dryer</td>
<td>1857</td>
<td>931</td>
<td>10.0</td>
<td>$240</td>
<td>41.8</td>
</tr>
<tr>
<td>Savings Percentage</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.
Dishwasher Change Out at a Large Hotel

- Existing flight machine was consistently breaking down after being in service for 20 years.
- Costing the hotel $12,000 a year to maintain.
- The flight conveyor was being operated by 1 or 2 staff members.
- Unit oversized, no longer meeting their needs to operate the restaurant and conference catering events.
- Executive chef and facilities director were looking to downsize to a rack-type conveyor.
Hot Water Use Profile

- **Inlet Temperature to Booster (°F)**
- **Outlet Temperature to Booster (°F)**
- **Electrical Use (kW)**
- **Flow Rate (gpm)**
Dishwasher Change Out in a Large Hotel

Original rackless conveyor used 360 gal/h rinse water continuously when the machine is in operation.

Downsize Dishwasher
Upsize Efficiency

FSTC recommended choosing a Best-in-Class model using 78 gal/h.
What’s happening here?

Dangling rinse sensor finger caused a 10 hour rinse cycle
## Surprise Savings From Downsizing

<table>
<thead>
<tr>
<th></th>
<th>Flight</th>
<th>66”-Rack</th>
<th>Percentage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in Operating Time (h/d)</td>
<td>9.1</td>
<td>2.9</td>
<td>68%</td>
</tr>
<tr>
<td>Reduction in Hot Water Use (gal/d)</td>
<td>3,700</td>
<td>395</td>
<td>89%</td>
</tr>
<tr>
<td>Reduction in Rinse Flow Rate (gpm)</td>
<td>6.0</td>
<td>1.5</td>
<td>75%</td>
</tr>
<tr>
<td>Daily Reduction in Gas Use (therms)*</td>
<td>50.4</td>
<td>4.2</td>
<td>92%</td>
</tr>
<tr>
<td>Daily Reduction in Electricity Use (kWh)*</td>
<td>398</td>
<td>179</td>
<td>55%</td>
</tr>
</tbody>
</table>

*Switched from an external gas booster heater on the original flight conveyor to a onboard electric booster heater on the new rack conveyor.
What We Monitored and Why?

Measured water and energy use and temperature

- Inlet water and temperature
- Prewash tank, wash tank, rinse tank and drain temps
- Electricity use of the conveyor and booster (if applicable)
- Estimated gas use at water heater

Needed the whole data “picture”
Flow profile of water/energy process

Washing and Rinsing Operation
Tank Dump
Tank Fill

- Hot In (gpm)
- Cold In (gpm)
- Hot Fill (°F)
- Final Rinse (°F)
- Drain Out (°F)
- Dishwasher (Wh)
- Booster (Wh)

Water Flow Rate and Electricity Use

Water Temperature

1:30 PM 2:00 PM 2:30 PM 3:00 PM
Question: What’s the best parameters to use for comparing conveyor dishmachines?

Considered 70 measured or calculated parameters:
- Total water or total energy
- Operational time: rinse, conveyor and span
- Flow rates

Answer: Normalized all data to total water or energy consumption per hour of rinse operation.
- Rinse time ~ value-added work time
Theoretical Specs VS. Actual Use

**Question:** How does the theoretical dishwasher water use (tank fill and rinse) per hour of rinse operation compare to actual water use?

\[
\dot{V}_{\text{theoretical}} (\text{gph}) = V_{\text{tank capacity}} \times \left( \frac{\text{Daily Tank Fills}}{t_{\text{Rinse}}} \right) + \dot{V}_{\text{Rated}} (\text{gph})
\]

\[
\dot{V}_{\text{actual}} (\text{gph}) = \frac{V_{\text{total (Rinse+Tank Fill+Tank Top Off)}}}{t_{\text{Rinse}}}
\]

**Answer:** Conventional units use 124% more water than spec  
High efficiency units use 67% more
**Water + Energy Use Per Hour Rinse**

- Massive savings when operating high-efficiency conveyors versus conventional models
- Best-in-class unit saved over 50% of water and energy use versus high-efficiency units

<table>
<thead>
<tr>
<th></th>
<th>Rated Rinse (gph)</th>
<th>Total Water Use Per Hour of Rinse (gph)</th>
<th>Water Savings vs. Low Efficiency</th>
<th>Total Energy Use Per Hour of Rinse (Btu/h)</th>
<th>Energy Savings vs. Low Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG. Low Eff. Rack (9)</td>
<td>275</td>
<td>663</td>
<td></td>
<td>962,000</td>
<td></td>
</tr>
<tr>
<td>AVG. High Eff. Rack (3)</td>
<td>132</td>
<td>304</td>
<td>54%</td>
<td>592,000</td>
<td>38%</td>
</tr>
<tr>
<td>AVG. Best In Class Rack (1)</td>
<td>78</td>
<td>135</td>
<td>80%</td>
<td>351,000</td>
<td>64%</td>
</tr>
</tbody>
</table>
Water + Energy Use Per Hour Rinse

Even larger savings measured with high-efficiency and best-in-class flight-conveyors!

Best-in-class unit saved over 50% of water and energy use versus high-efficiency units

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<tr>
<td>AVG. Low Eff. Flight (4)</td>
<td>277</td>
<td>1114</td>
<td></td>
<td>1,807,000</td>
<td></td>
</tr>
<tr>
<td>AVG. High Eff. Flight (4)</td>
<td>85</td>
<td>282</td>
<td>75%</td>
<td>685,000</td>
<td>62%</td>
</tr>
<tr>
<td>AVG. Best In Class Flight (1)</td>
<td>87</td>
<td>143</td>
<td>87%</td>
<td>393,000</td>
<td>78%</td>
</tr>
</tbody>
</table>
Water + Energy Use Per Hour Rinse

- Can clearly see the savings opportunity for replacement
- Additional testing of Best-In-Class Units needed
Rinse Flow Rate Should No Longer be the Default Efficiency Parameter

- With all 22 units tested, the rated rinse flow rate accounted for 35% of total use
- With best-in-class, rated rinse accounted for 59% of total use
- Incentive, standards and recognition programs (ENERGY STAR®, LEED, ASHRAE 189.1) need to take a more comprehensive approach

<table>
<thead>
<tr>
<th>Conveyor 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>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Rack</td>
<td>275</td>
<td>663</td>
<td>41%</td>
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<tr>
<td>High-Efficiency Rack</td>
<td>132</td>
<td>304</td>
<td>43%</td>
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<tr>
<td>Best-In-Class Rack</td>
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Reasons for the Disparity

- Rated rinse doesn’t account for routine tank fill operations
- Overspray from washing large back of the house items, especially flat wares such as sheet pans and cutting boards was the leading cause of water waste
- 44” and 66” rack conveyors are prone to overspray due to the small separation between tanks
- Leaving the tank drain open or debris stuck in valve were the second leading cause of waste
- Dishwasher components fail and maintenance is not completed
Recommendations for Integration

Long term solution: Built-in permanent electricity and water sub-meters, data logging and wireless transfer capability

Helps dishwashers to maintain savings throughout life:

- Provides water + energy use and operating time info
- Easy benchmarking of machine and staff operations
- Smart dishwasher overcomes operator error
  - Can’t rinse with drain open
  - Auto clean and delime settings
- Green-eye technology, active tank filtering system
Meter Your Existing Dishwasher’s Water Use

Inexpensive ($500-$1000)

- Identify operating behaviors and train staff accordingly
- Identify maintenance shortcomings and identify solutions
- Set water, energy and detergent use benchmarks for operation, able to recheck periodically
- Support custom water and energy rebate process
- Have a business-case for replacement project “shovel ready” for when the opportunity arises
Smart Metering Available

Current utility water metering practice

▶ Provides water + energy use and operating time info
▶ Water use data is typically provided in one or two month intervals
▶ This is too low of a resolution

Low cost ($350) smart metering is available!

▶ 5-min interval metering using 3G cellular
▶ 10-year plan
▶ Data stored on server for easy download
▶ Leak detection
High-Temperature Dishwashers with Heat Recovery Can Save Even More Energy

- Exhaust-air heat recovery (EAHR) preheats incoming cold water saving energy at the water heater.
- Cold water passes through copper pipes while a fan extracts steam and forces it through thin aluminum plates. The steam condenses on the cold fins and the latent heat is transferred to the cold incoming water.
- The cold supply water at a minimum of 50°F can be preheated to 110-130°F before reaching the booster.
Utilizing Exhaust-Air Heat Recovery

- In door-type machines, EAHR may eliminate the need for dedicated exhaust ventilation system.
- Heat pumps can be utilized as a second level of heat recovery to additionally increase the temperature of preheated water.
- In rack and flight conveyors the addition of a heat pump for dehumidification is required to be ventless.

**Exhaust-Air Temperature**

- without EAHR: 110 to 130°F
- with EAHR: 70 to 80°F
- and Heat Pump: 60 to 70°F
EAHR Dishwashers Available in the U.S.

Flight Conveyor:

Added Heat Pump with recently introduced model
Overcoming Distortions in the Market

Operators need unbiased advise to overcome knowledge gap:

- Frequently, the decision making process for replacing an older dishwasher involves comparing multiple manufacturer’s estimated savings claims based on rated rinse.

- When comparing several units that are all ENERGY STAR certified at similar rinse flow rates, it’s easy to assume that the units have similar operating costs.

- Decision making get refined to simply comparing the purchase and install cost quotes along with marketing claims.

- Deemed or custom water and energy rebates by the utility are not typically factored in, nor is 1st-year cost or 10th-year cost (life-cycle cost) calculations.

- Operators can easily select a unit that looks good on paper but doesn’t deliver in operating savings over its useful life.
Solutions to Overcome Knowledge Gap

- Development of advanced life-cycle cost calculators
- Refinement of custom rebates that would require the installation of permanent water meters to sub-meter use
- 3rd-party unbiased retro-commissioning and dishwasher replacement program funded by joint water and energy utilities
- Development and circulation of design guides and detailed case studies
Savings is only achievable in the sanitation room through a combination of practices:

- Specify properly sized and efficient dishwashers and pre-rinse equipment
- Add permanent submetering to properly commission equipment and for benchmarking
- Continuous training program for staff
- Experienced maintenance staff

Best-in-class dishwashers are worth the additional investment and additional incentive!
Or we can Maintain the Status Quo
Questions?

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Thanks for Listening!