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# Results of 22 Monitoring Projects on Conveyor Dishwashers in Commercial Kitchens

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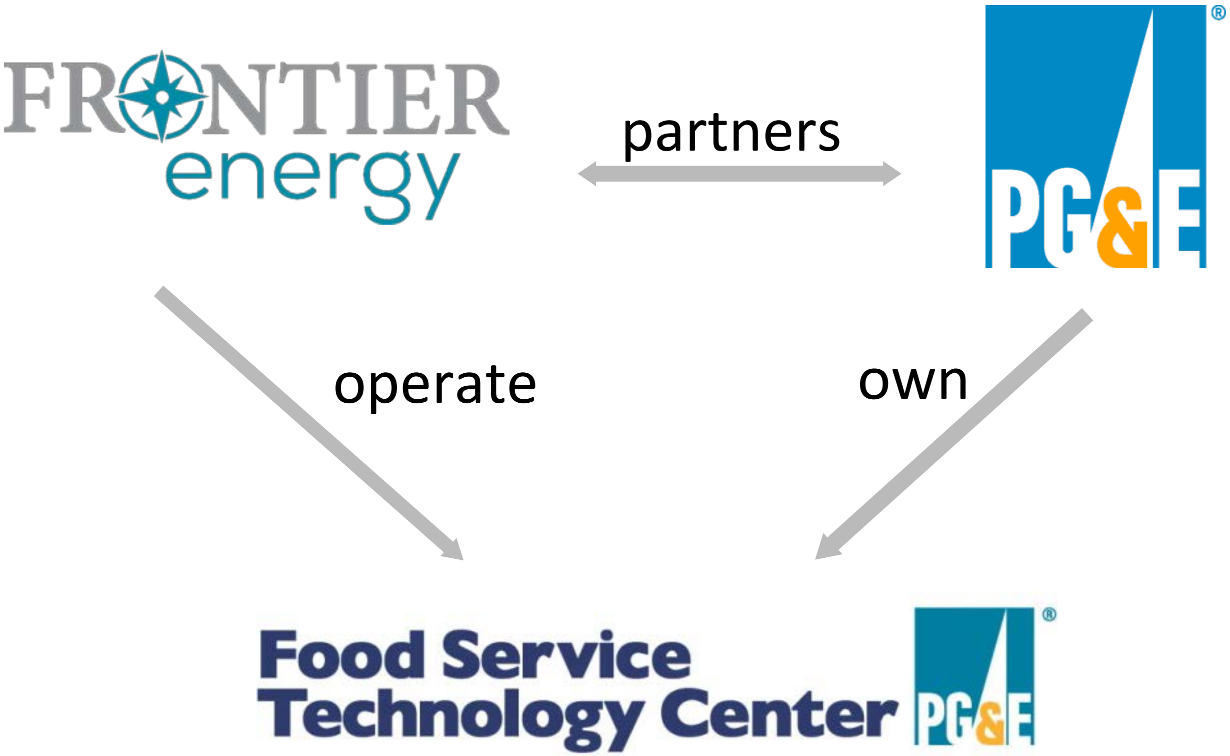
**October 6th, 2017**

*Presentation by:*

Amin Delagah

Research/Project Engineer

# 30 Years of Partnership

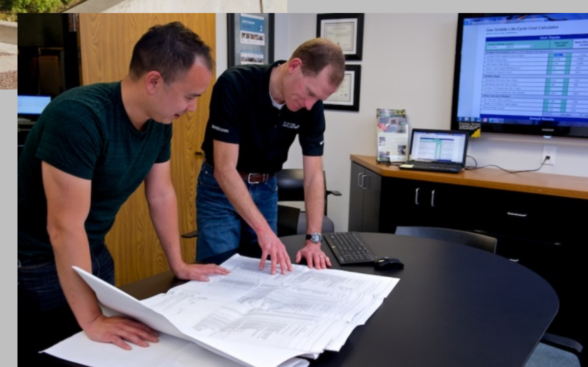



**The Food Service Technology Center (FSTC) is an unbiased energy-efficiency research program funded by California utility customers.**

Appliance Testing

Seminars

Energy Audits



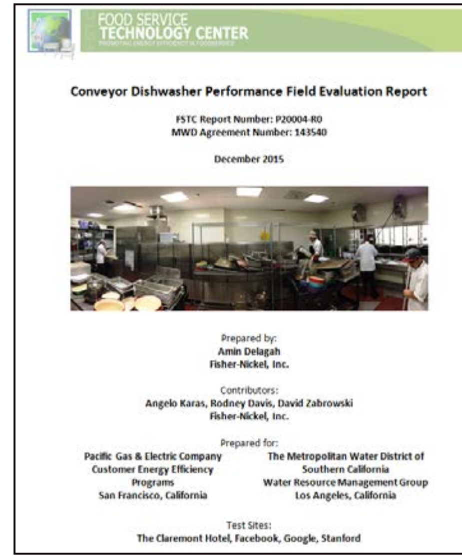
Facility Design

# 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](http://bewaterwise.com/ICP_projects.shtml)


FOOD SERVICE TECHNOLOGY CENTER

Conveyor Dishwasher Performance Field Evaluation Report

FSTC Report Number: P20004-R0
MWD Agreement Number: 143540

December 2015

Prepared by:
Amin Delagah
Fisher-Nickel, Inc.

Contributors:
Angelo Karas, Rodney Davis, David Zabrowski
Fisher-Nickel, Inc.

Prepared for:

Pacific Gas & Electric Company
Customer Energy Efficiency Programs
San Francisco, California

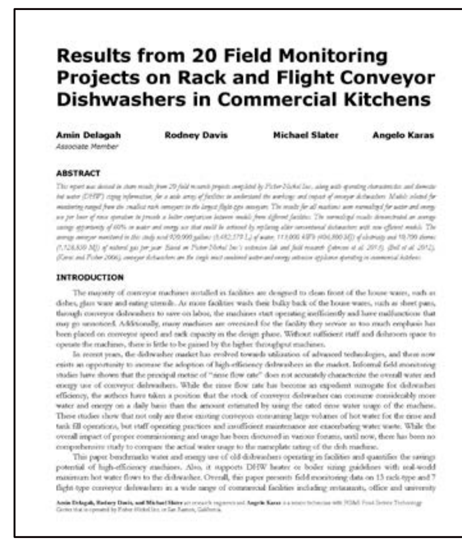
The Metropolitan Water District of Southern California
Water Resource Management Group
Los Angeles, California

Test Sites:
The Claremont Hotel, Facebook, Google, Stanford

## 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](http://www.techstreet.com/searches/17148009)


**Results from 20 Field Monitoring Projects on Rack and Flight Conveyor Dishwashers in Commercial Kitchens**

Amin Delagah, *Associate Member* — Rodney Davis — Michael Slater — Angelo Karas

ABSTRACT

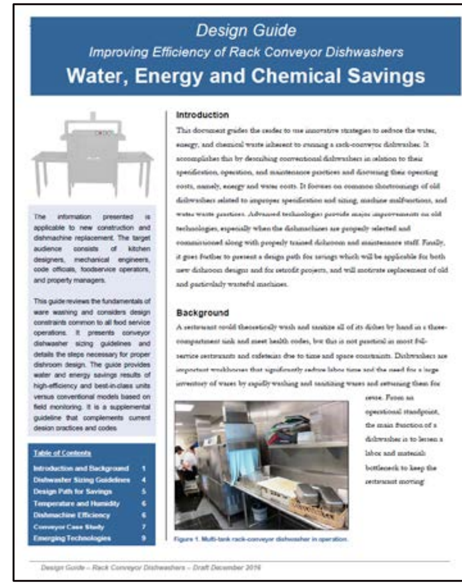
INTRODUCTION

# 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/](https://fishnick.com/design/dishwashers/)



Design Guide

*Improving Efficiency of Rack Conveyor Dishwashers*

**Water, Energy and Chemical Savings**

The information presented is applicable to new construction and dishmachine replacement. The target audience consists of kitchen designers, mechanical engineers, code officials, foodservice operators, and property managers.

This guide reviews the fundamentals of ware washing and considers design constraints common to all food service operations. It presents conveyor dishwasher sizing guidelines and details the steps necessary for proper dishroom design. The guide provides water and energy savings results of high-efficiency and best-in-class units versus conventional models based on field monitoring. It is a supplemental guideline that complements current design practices and codes.

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**Introduction**

This document guides the reader to use innovative strategies to reduce the water, energy, and chemical waste inherent to running a rack-conveyor dishwasher. It accomplishes this by describing conventional dishwashers in relation to their specification, operation, and maintenance practices and discussing their operating costs, namely, energy and water costs. It focuses on common shortcomings of old dishwashers related to improper specification and sizing, machine malfunctions, and water waste practices. Advanced technologies provide major improvements on old technologies, especially when the dishmachines are properly selected and commissioned along with properly trained dishroom and maintenance staff. Finally, it goes further to present a design path for savings which will be applicable for both new dishroom designs and for retrofit projects, and will motivate replacement of old and particularly wasteful machines.

**Background**

A restaurant could theoretically wash and sanitize all of its dishes by hand in a three-compartment sink and meet health codes, but this is not practical in most full-service restaurants and cafeterias due to time and space constraints. Dishwashers are important workhorses that significantly reduce labor time and the need for a large inventory of wares by rapidly washing and sanitizing wares and returning them for reuse. From an operational standpoint, the main function of a dishwasher is to lessen a labor and materials bottleneck to keep the restaurant moving.

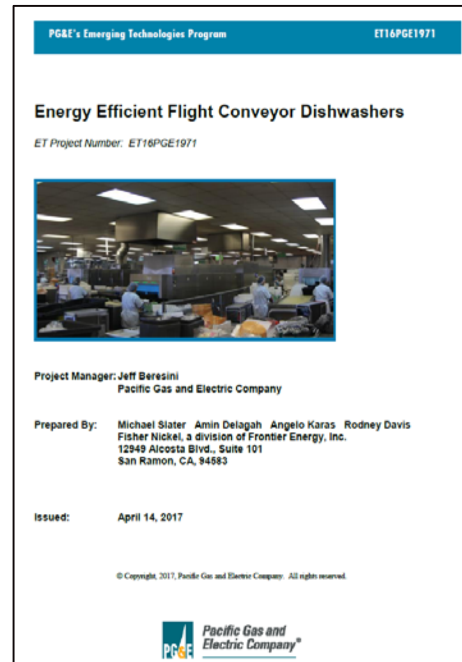
Figure 1. Multi-tank rack-conveyor dishwasher in operation.

Design Guide – Rack Conveyor Dishwashers – Draft December 2016

## 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](http://www.etcc-ca.com/reports/energy-efficient-flight-conveyor-dishwashers)



PG&E's Emerging Technologies Program ET16PGE1971

**Energy Efficient Flight Conveyor Dishwashers**

*ET Project Number: ET16PGE1971*

Project Manager: Jeff Beresini
Pacific Gas and Electric Company

Prepared By: Michael Slater Amin Delagah Angelo Karas Rodney Davis
Fisher Nickel, a division of Frontier Energy, Inc.
12949 Alcosta Blvd., Suite 101
San Ramon, CA, 94583

Issued: April 14, 2017



Pacific Gas and Electric Company®

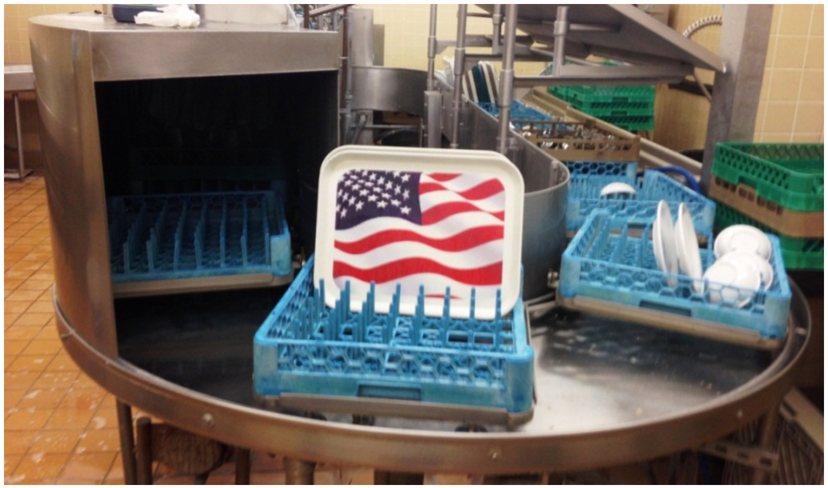
# Learning Objectives

- 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

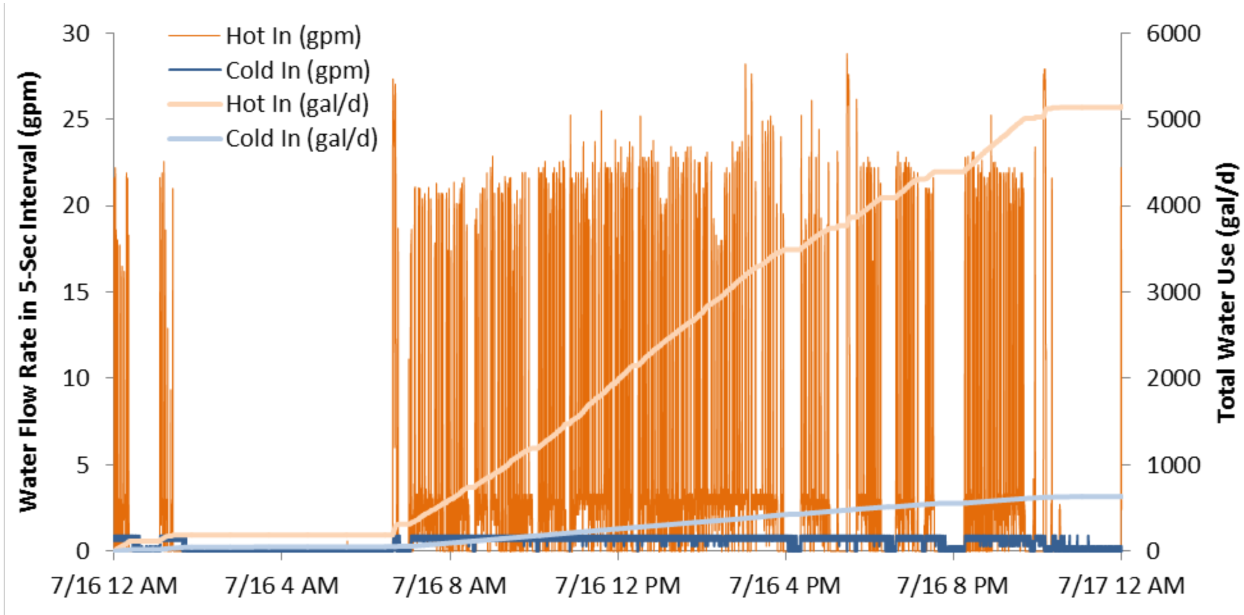
- Most units were found in poor condition
- Shocking water use for tank filling and top off operations

### Dishwasher Projects

- 7 Hotels, 3 Restaurants
- 10 School, Commercial, Army Cafeterias
- 2 Airline Catering Facility

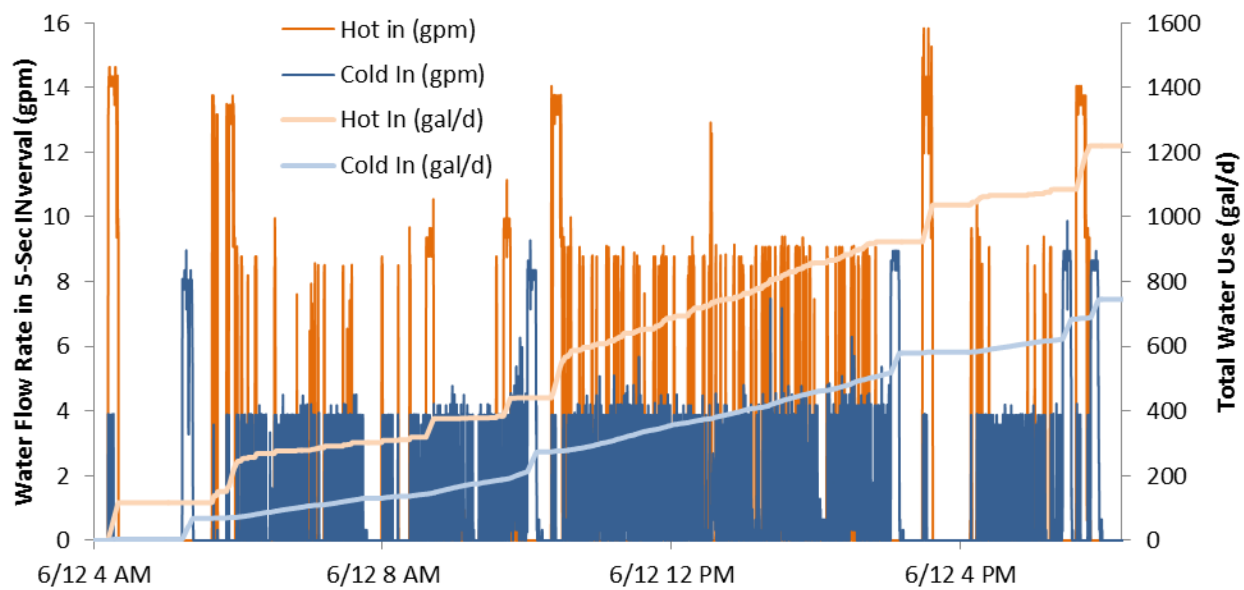
# Original Dishwasher in Work Cafeteria

- **98 gph** spec. rinse flow rate
- **189 gph** measured rinse flow rate
- The high flow rate and high drain temperatures where 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

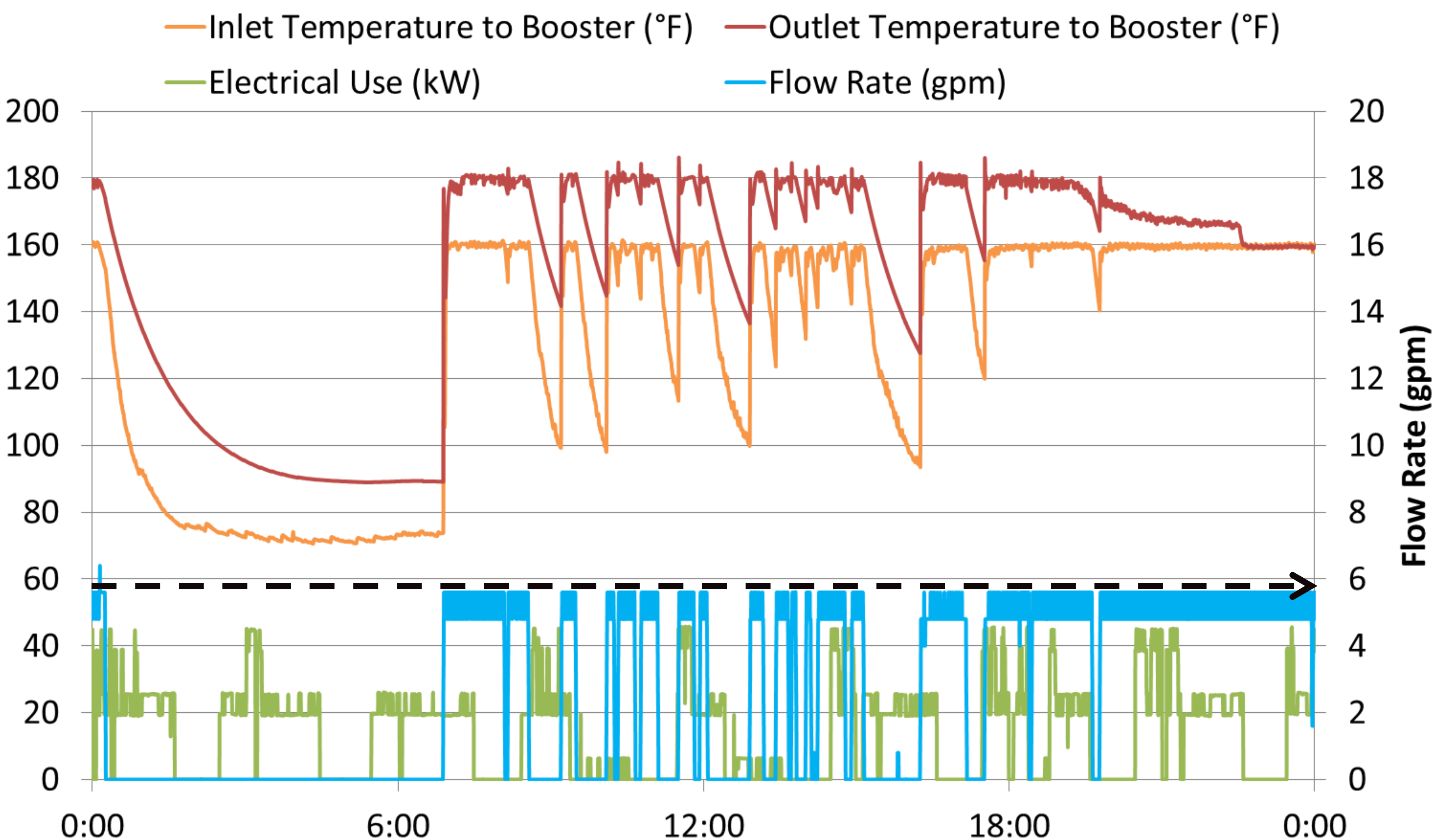
| | Water Use (gal/d) | Electricity Use (kWh/d) | Gas Use (therms/d) | Utility Cost ($/d) | Total Energy Use (therms/d) |
|---|---|---|---|---|---|
| Original Flight Conveyor Dishwasher | 5656 | 668 | 48.0 | $271 | 70.8 |
| Replacement Flight Conveyor w/ Heat Recovery + Blower Dryer | 1857 | 931 | 10.0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

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



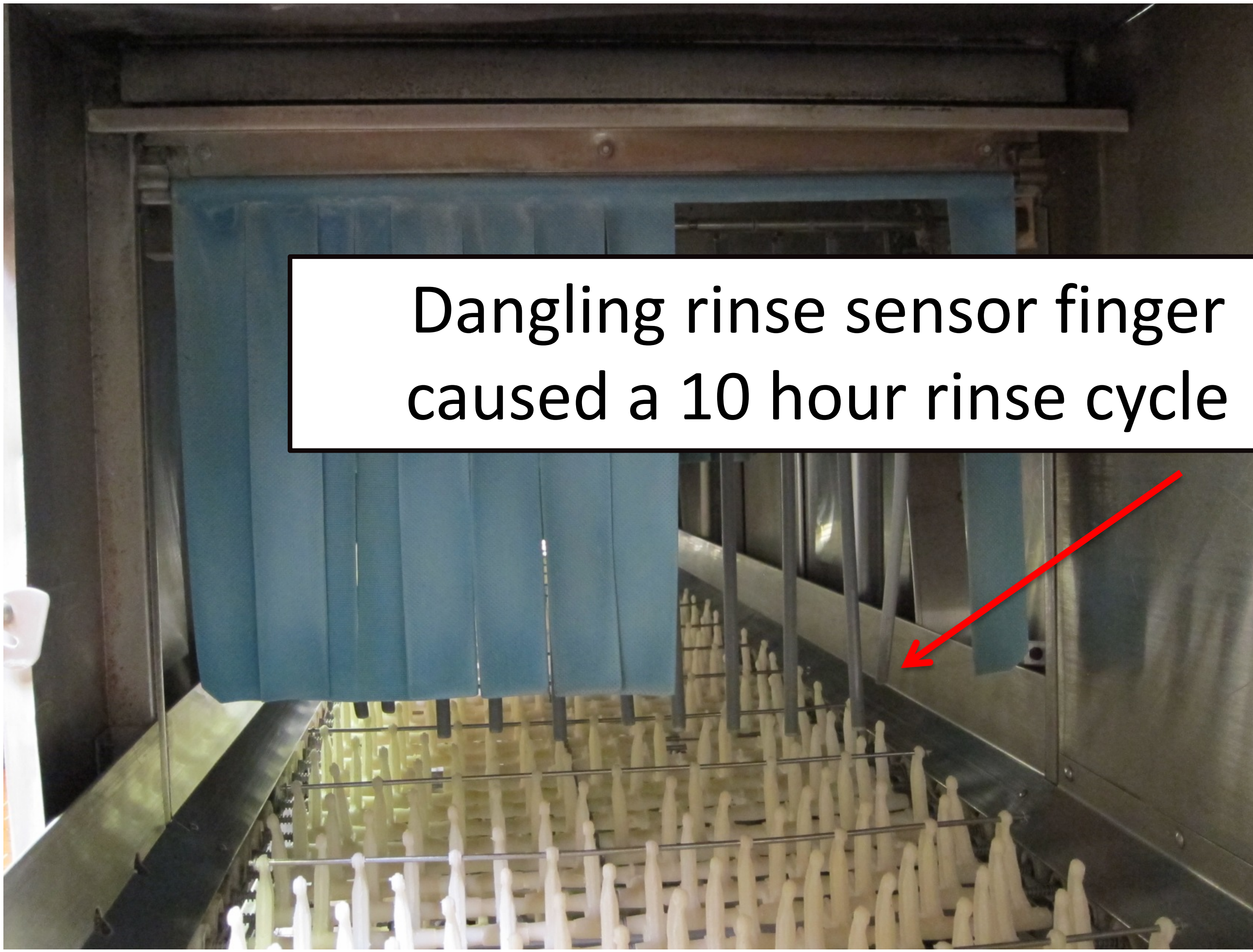
# Dishwasher Change Out in a Large Hotel

**Downsize Dishwasher**
**Upsize Efficiency**

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

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

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

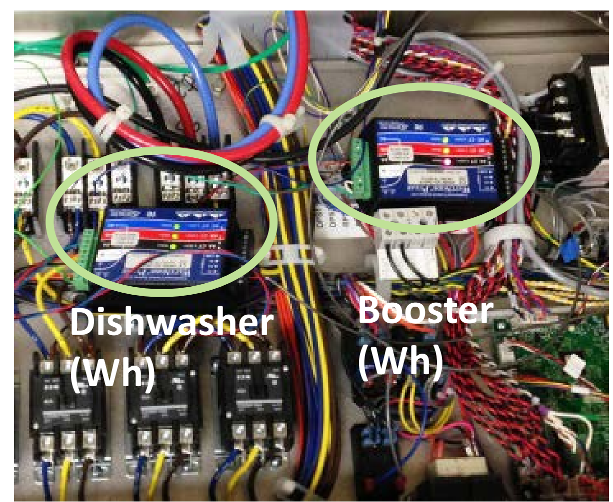
*Switched from an external  gas booster heater on the original flight conveyor to a on-board electric booster heater on the new rack conveyor.

# What We Monitored and Why?

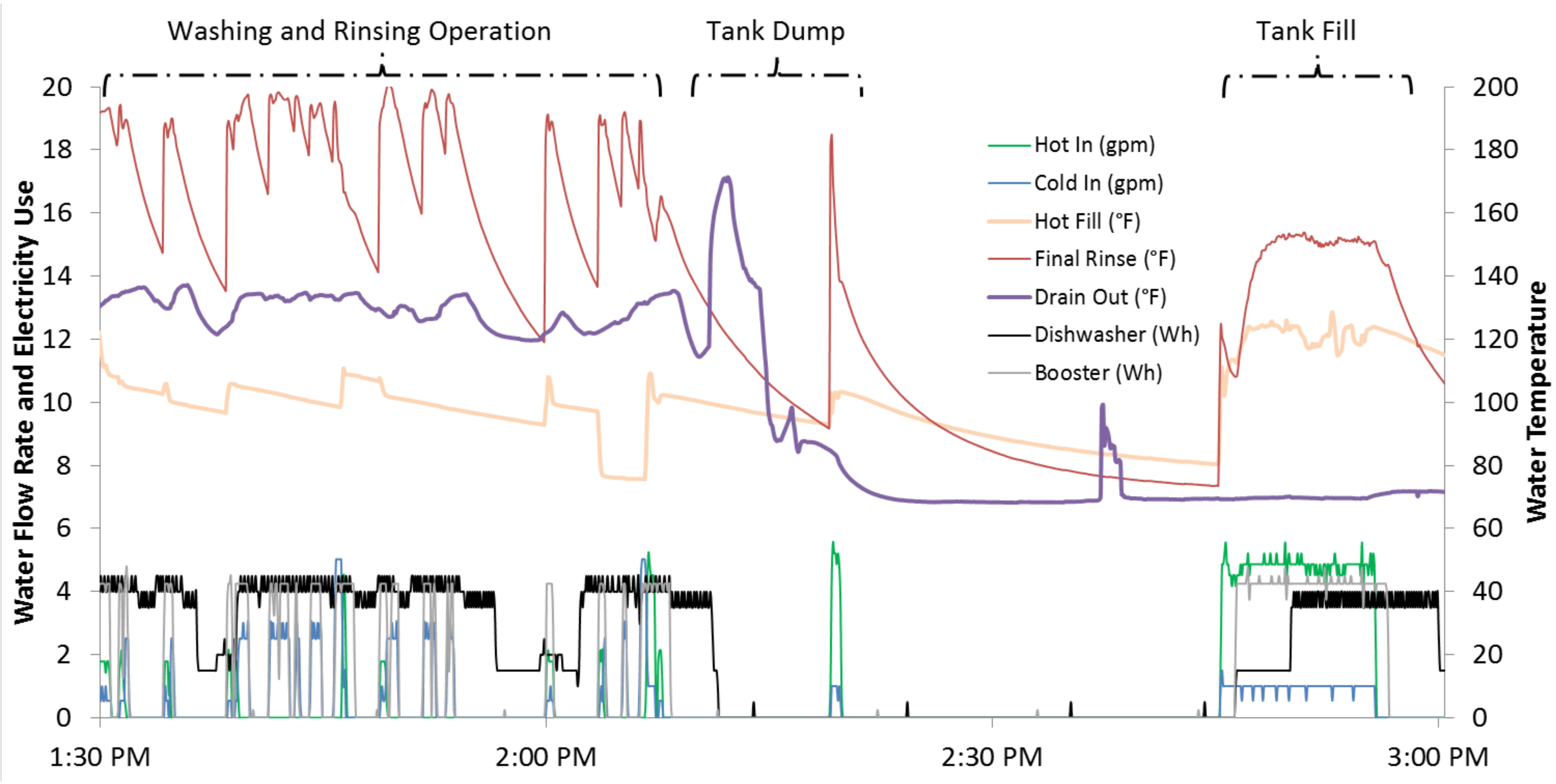
Measured water and energy use and temperature

- 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



# Conveyor Dishwasher Monitoring




**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?

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

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

**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

| | Rated Rinse (gph) | Total Water Use Per Hour of Rinse (gph) | Water Savings vs. Low Efficiency | Total Energy Use Per Hour of Rinse (Btu/h) | Energy Savings vs. Low Efficiency |
|---|---|---|---|---|---|
| AVG. Low Eff. Rack (9) | 275 | 663 | | 962,000 | |
| AVG. High Eff. Rack (3) | 132 | 304 | **54%** | 592,000 | **38%** |
| AVG. Best In Class Rack (1) | 78 | 135 | **80%** | 351,000 | **64%** |

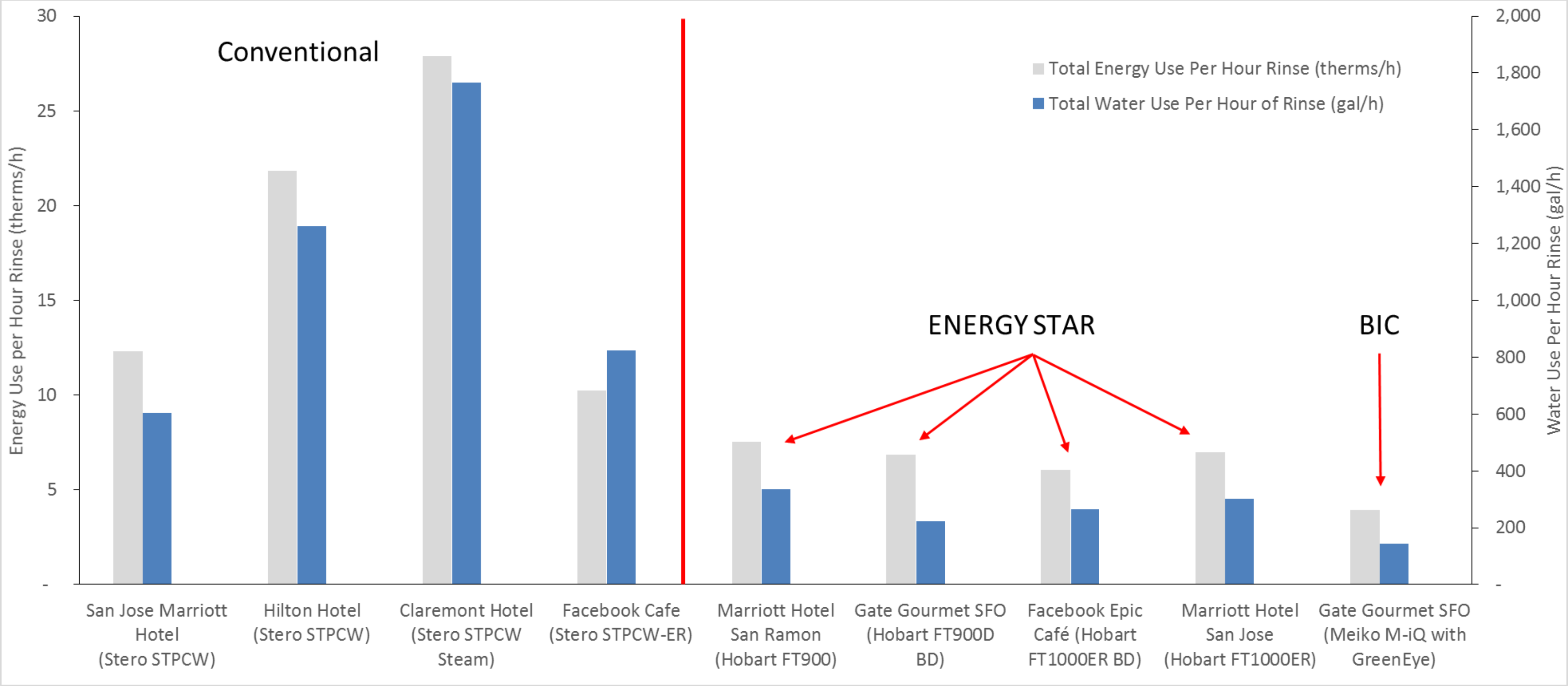
# Water + Energy Use Per Hour Rinse

- 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

| | Rated Rinse (gph) | Total Water Use Per Hour of Rinse (gph) | Water Savings vs. Low Efficiency | Total Energy Use Per Hour of Rinse (Btu/h) | Energy Savings vs. Low Efficiency |
|---|---|---|---|---|---|
| AVG. Low Eff. Flight (4) | 277 | 1114 | | 1,807,000 | |
| AVG. High Eff. Flight (4) | 85 | 282 | **75%** | 685,000 | **62%** |
| AVG. Best In Class Flight (1) | 87 | 143 | **87%** | 393,000 | **78%** |

# 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

| Conveyor Type | Specified Rinse Flow Rate (gph) | Water Use Per Hour of Rinse Operation (gph) | Rinse Divided by Real World Water Use |
|---|---|---|---|
| Conventional Rack | 275 | 663 | 41% |
| High-Efficiency Rack | 132 | 304 | 43% |
| Best-In-Class Rack | 78 | 135 | 58% |
| Conventional Flight | 277 | 1114 | 25% |
| High-Efficiency Flight | 85 | 282 | 30% |
| Best-In-Class Flight | 87 | 143 | 61% |

# Reasons for the Disparity

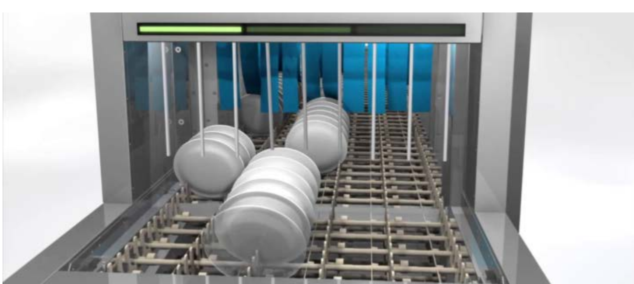
- Rated rinse doesn't account for routine tank fill operations
- Overspray from washing large back of the house items, especially flat wares such as sheet pans and cutting boards was the leading cause of water waste
- 44" and 66" rack conveyors are prone to overspray due to the small separation between 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

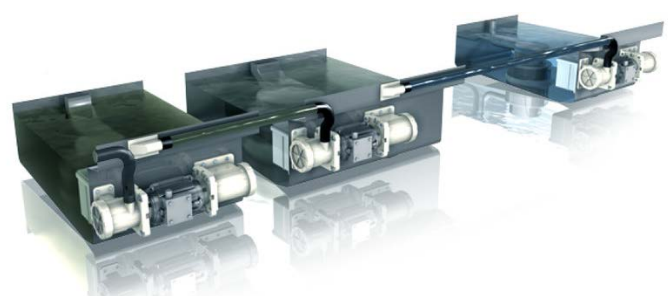
# Recommendations for Integration

**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

***Innov8 Smart Register***

MetronFarnier

Advanced Single-Jet Technology

# 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.

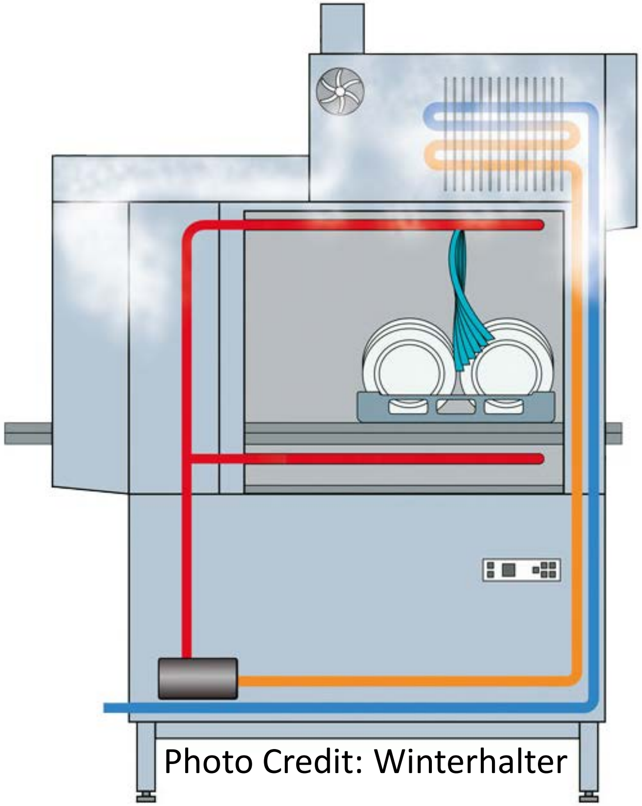


Photo Credit: Winterhalter

# 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.

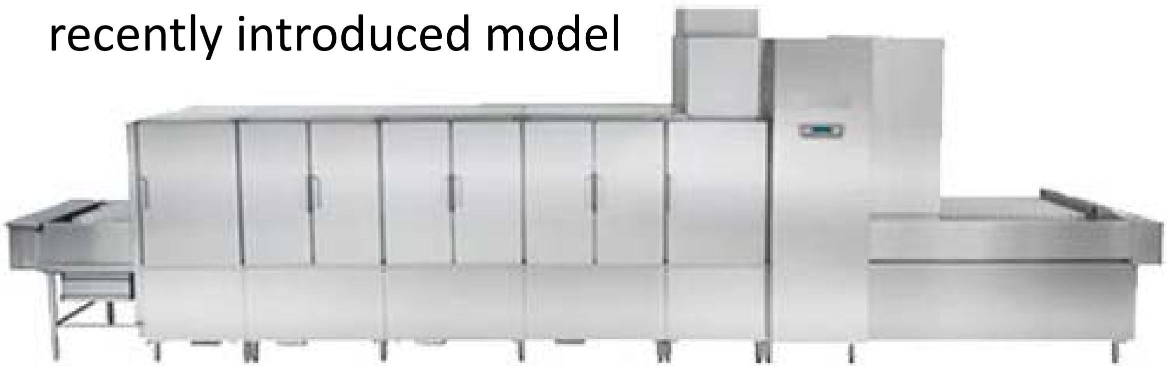
<u>Exhaust-Air Temperature</u>

| | |
|---|---|
| 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



MEIKO

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Champion

# 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, its 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

**Dishmachine Life Cycle Cost Calculator**

About | How To Use | Definitions

| User Inputs | | | |
|---|---|---|---|
| | User Input Dishmachine | Base Efficiency Dishmachine | ENERGY STAR® Dishmachine |
| **Dishmachine Performance** *(Based on ASTM Standard Test Methods F1696 & F1920)* | | | |
| Dishmachine Type (Select from Box at Right) | Door Type | Door Type | Door Type |
| Low or High Temperature (Select from Box at Right) | High Temperature | High Temperature | High Temperature |
| Gallons per Rack (gal/rack) | | 1.10 | 0.89 |
| **Dishmachine Usage** | | | |
| Racks per Day (racks/day) | | 141 | 141 |
| Operating Days per Year (d/year) | | 365 | 365 |
| **Water Heating System** | | | |
| Water Heater Type (Select from Box at Right) | Std Efficiency Gas | Std Efficiency Gas | Std Efficiency Gas |
| Water Heating System Efficiency (%) | 68.0 | 68.0 | 68.0 |
| Dishmachine Supply Temperature (°F) | 140 | 140 | 140 |
| **Dishmachine Booster Heater** | | | |
| Booster Heater Type (Select from Box at Right) | Electric | Electric | Electric |
| Booster Heater Efficiency (%) | 95.0 | 95.0 | 95.0 |
| **Utility Cost and Lifespan** | | | |
| Choose State (Optional) | CA | CA | CA |
| Electric Cost per kWh ($/kWh) | 0.1394 | 0.1394 | 0.1394 |
| Electric Demand Charge per kW ($/kW) | 0.00 | 0.00 | 0.00 |
| Gas Cost per Therm ($/therm) | 0.884 | 0.884 | 0.884 |
| Water / Sewer Cost per CCF (100 ft$^3$) | 7.00 | 7.00 | 7.00 |
| Lifespan of Dishmachine in Years (years) | 12.0 | 12.0 | 12.0 |
| Discount Rate (%/year) | 0.00 | 0.00 | 0.00 |
| | Calculate! | Reset Fields | |
| **Annual Results** | | | |
| Annual Electric Energy Consumption (kWh) | | | |
| Annual Gas Energy Consumption (Therms) | | | |
| Annual Water Consumption (gal) | | | |
| Annual Electric Energy Cost | $ | $ | $ |
| Annual Gas Energy Cost | $ | $ | $ |
| Annual Water Cost | $ | $ | $ |
| Total Annual Utility Cost | $ | $ | $ |
| **Input Additional Costs (Optional)** | | | |
| Maintenance Costs per Year | $ 0 | $ 0 | $ 0 |
| Initial Cost of Dishmachine | $ 0 | $ 0 | $ 0 |
| **Lifetime Results** | | | |
| Lifetime Energy Cost | $ | $ | $ |
| Lifetime Water Cost | $ | $ | $ |
| Lifetime Maintenance Cost | $ | $ | $ |
| Initial Cost of Dishmachine | $ | $ | $ |

# In Closing…

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!

Low cost wireless submetering now available offering 5-min interval metering using 3G cellular network

# Or we can Maintain the Status Quo

# Questions?

**Amin Delagah**
*Project/Research Engineer*
PG&E Food Service Technology Center
adelagah@frontierenergy.com

# Thanks for Listening!