

FINAL REPORT

Energy and Water Efficiency Improvements for Dishrooms in
Military Dining Facilities

ESTCP Project EW-201518

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Gas Technology Institute

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ABSTRACT

INTRODUCTION AND OBJECTIVES

Energy and water usage for commercial foodservice have a significant impact on the overall usage of a facility. Daily meal preparation and cleanup in a military dining facility (DFAC) represents more than 75% of the energy and water load of the facility. Many of the dishwashers installed in foodservice facilities and DFACs are older, use excessive volumes of hot water and are being operated inefficiently. The objective of this project was to identify and demonstrate a comprehensive strategy of installing and analyzing new technologies to reduce the energy and water usage and intensity within a dishroom at a military installation used for cleaning and sanitizing of flatware, dishes, cooking vessels and other foodservice related utensils. Quantifiable objectives include 60% energy savings and 75% savings for water for dishwashing.

TECHNOLOGY DESCRIPTION

The project demonstrated three types of technologies: waste water heat recovery, optimized ventilation system and a low-water usage warewasher or dish machine. The dish machine cleans dishware and other items producing steam and hot waste water at various rates depending on the load sizes. The ventilation system vents the steam produced by the dish machine but is typically not set to ventilate at the correct rate to ensure an optimal working environment in terms of comfort. A waste water recovery system reuses heat from the waste water to preheat inlet water to the dish machine that would otherwise be literally poured down the drain.

PERFORMANCE AND COST ASSESSMENT

This project identified and demonstrated a dish machine with waste water heat recovery to reduce the energy and water usage and energy intensity within a dishroom at a military installation used for cleaning and sanitizing of flatware, dishes, cooking vessels and other foodservice related utensils. Results showed a savings of 35 therms per day of natural gas and 6,375 gallons of water per day when replacing the existing machine with an energy efficient design. These savings equate to 12,775 therms per year and 2.33 million gallons of water per year. Based on the equipment and installation costs from the demonstration of \$136,405 and total yearly cost savings of 60,786, the system simple payback is 2.24 years or about 27 months.

IMPLEMENTATION ISSUES

The main implementation issue was training the DFAC staff to use the new dish machine with the new dishroom layout. The Best Practices Guide for this project further details some of the installation issues for this project.

PUBLICATIONS

ASHRAE 2016, Comfort Challenges in Commercial Kitchens, Seminar by Don Fisher for 05.10

Kitchen Ventilation, 04.01 Load Calculation Data and Procedures

ASHRAE 2017, Paper & Poster by Don Fisher and Alex Zhivov, Comparison of Approaches to

Deep Energy Retrofit of Buildings with Low and High Internal Loads and Ventilation
Requirements

SERDP & ESTCP Symposium 2017 & 2018, Posters by Frank Johnson

ACEEE Water Forum 2018, Presentation by Don Fisher and Amin Delagah

ACRONYMS AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
Btu	British thermal unit
C&P	Cost & Performance Report
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CERL	Construction Engineering Research Laboratory
CFM	Cubic feet per minute
DFAC	Dining Facility
DLIFLC	Defense Language Institute Foreign Language
DoD	Department of Defense
EO	Executive Order
EP	Execution Plan
EPA	U.S. Environmental Protection Agency
EQ	Equipment Selection
ESCOs	Energy Service Companies
ETP	Emerging Technology Program
ESTCP	Environmental Security Technology Certification Program
EW	Energy and Water
FEMP	Federal Energy Management Program
FNi	Fisher Nickel, Inc.
FR	Final Report
GFX	Gravity-Film Heat Exchanger
gpm	gallons per minute
GTI	Gas Technology Institute
HVAC	Heating, Ventilation and Air-Conditioning
IPR	In Process Review
kW	kilowatt
lb/hr	pounds per hour
LCCA	life-cycle cost analysis
MW	megawatt
NIST	National Institute of Standards & Technology

OAC	Outdoor Airload Calculator
O&M	operation and maintenance
RCRA	Resource Conservation and Recovery Act
SCADA	Supervisory Control and Data Acquisition
SCFM	standard cubic feet per minute
SERDP	Strategic Environmental Research and Development Program
SIR	Savings to Investment Ratio
THC	total hydrocarbon
UESC	Federal Utility Energy Service Company
UFC	Unified Facilities Criteria
USAG	United States Army Garrison
UTD	Utilization Technology Development

EXECUTIVE SUMMARY

INTRODUCTION

Energy and water usage for commercial foodservice have a significant impact on the overall usage of a facility. Daily meal preparation and cleanup in a military dining facility (DFAC) represents more than 75% of the energy and water load. Within the foodservice facility itself, the dishwashing room or “dishroom” has the highest energy intensity compared to the other zones within a DFAC (ASHRAE, 2012). The dishroom has an intensity of 53.5 W/ft², compared to 29.3 W/ft² for the Carry Out zone, 27.1 W/ft² for the Server zone and 13.5 W/ft² for the Kitchen zone. Up to 75% of the hot water in the kitchen is consumed in the dishroom. Many of the dishwashers installed in foodservice facilities and DFACs are older, use excessive volumes of hot water and are being operated inefficiently. Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dishwashers with modern ENERGY STAR® qualified models. Recent findings have shown that not only are these existing dishwashers (also called warewashers or dish machines) consuming large volumes of hot water for the rinse operation, but also the staff operating practices are greatly adding to additional water waste. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy (formally known as Fisher Nickel, Inc). While energy-efficient cooking equipment, improved ventilation systems and advanced space conditions systems have been developed and used for the kitchen, dining, and serving zones; the dishroom has experienced fewer improvements in energy and water usage for all types of foodservice facilities including DFACs.

OBJECTIVES

The objective of this project was to identify and demonstrate a comprehensive strategy of installing and analyzing new technologies to reduce the energy and water usage and energy intensity within a dishroom at a military installation used for cleaning and sanitizing of flatware, dishes, cooking vessels and other foodservice related utensils. Included are technologies to recover heat from waste water, to reduce waste water, to improve worker environmental conditions, demonstrate reliability and to reduce space conditioning loads. The specific Performance Objectives are: 60% energy savings for heating water to the dishwasher, 30% energy savings for the ventilation system including fan power and energy to condition indoor air and 75% savings for water for washing. The results of this project were used for a Best Practices Guide and workshop presentation to assist energy managers, consultants and commercial foodservice contractors at DoD locations to recognize the benefits of the dishroom technologies demonstrated. The ventilation results were used as the basis for establishing dishroom ventilation standards that do not exist for any foodservice applications.

TECHNOLOGY DESCRIPTION

To achieve the objective of reducing energy and water usage in dishroom installations, the project team led by Gas Technology Institute (GTI) demonstrated three types of technologies: waste water heat recovery, optimized ventilation system and a low-water usage warewasher or dish machine. An optimal savings potential can be achieved from the three technologies based on the interrelationship between them. The dish machine cleans dishware and other items producing

steam and hot waste water at various rates depending on the load sizes. The ventilation system vents the steam produced by the dish machine but is typically not set to ventilate at the correct rate to ensure an optimal working environment in terms of comfort. A waste water recovery system reuses heat from the waste water to preheat inlet water to the dish machine that would otherwise be literally poured down the drain. By recovering waste heat and adjusting the ventilation rate, less energy and water is used to clean the dishes and to maintain a comfortable work environment.

At the start of this project, two technologies existed to recover the heat from the drain. The Gravity-Film Heat Exchanger (GFX) is a vertical counterflow heat exchanger to transfer heat from the drain water to the incoming water of the dishwasher (Figure E1). Waste water flows through a 2 to 4 inch central copper pipe with a ½ inch copper coil wrapped around it and is the supply line to the dish machine. The coils are slightly flattened to increase surface area and thus improve heat transfer.



Figure E1. GFX Schematic and Novothermic NVX2060 (L to R)

The other technology was the Novothermic NVX2060 Heat Exchanger, also shown in Figure E1. This unit is also a heat exchanger for transferring heat from the drain to the supply water of the dishwasher. This unit is a standalone positioned next to or underneath the washer and requires a power source. After an initial evaluation of the proposed demonstration site at US Army Garrison Presidio of Monterey, the Novothermic was the leading candidate based on the type of warewasher and the layout of the dish room.

During the baseline testing, a new dish machine manufactured by Hobart became available that had built in heat recovery. The Hobart CLPS86ER is a conveyor style dish machine that has an internal heat exchanger for recovering heat from the waste water to reuse for heating new wash water. After discussions with the manufacturer and host site, the project team requested and was granted a change of scope to switch to this unit. The advantages of on-board vs. external heat recovery are that technical support would be consolidated with a single manufacturer for both the heat recovery unit and the dish machine, and additional floor space in the already tight dish room would not be needed for an external unit.

In accordance with ASTM F1920, Standard Test Method for Performance of Rack Conveyor, Commercial Dishwashing Machines with canopy exhaust, hoods shall use a 3 foot by 6-foot configuration for operating at the dishwashing machine manufacturer's specified ventilation rate. Typically, the exhaust hood operates at too high of a ventilation rate, resulting in more air being removed from the dishroom and pulling excess air from the rest of DFAC. This results in energy being wasted because the excess air typically has been heated or air-conditioned for the comfort of the occupants.

Warewashers or dish machines are available in three designs for the washing and sanitizing of items including plates, eating utensils, and cooking utensils: flight type, rack conveyor, and stationary door. The designs vary to meet cleaning volumes and cleaning rates. Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dishwashers with modern ENERGY STAR® qualified models. Recent findings have shown that not only are these existing dishwashers consuming large volumes of hot water for the rinse operation, but also the staff operating practices are greatly adding to additional water waste. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy. The most common design for dish machine is the use of electric heating elements to heat the water. Despite a majority of most commercial foodservice appliance types using natural gas as the fuel source, dish machines are over 95% electric. The main reason is electric dish machines are easier to design and manufacture because there is limited space available within the confines of the unit for positioning a gas-fired water heating system including a burner, tank, gas train, and vent. The current state of the art for natural gas dish machines is to use an external gas-fired booster heater to preheat the water to the dish machine with an electrical heating element to heat the water to the final rinsing and washing temperatures.

PERFORMANCE ASSESSMENT

Figure E2 shows the existing (baseline) carousel machine and the replacement (demonstration) machine installed in the dish room at the test site.



Figure E2. Baseline and Demonstration Dish Machines (L to R)

The key to acquiring accurate data for assessing the quantitative and qualitative performance objectives was establishing several difference performance characteristics of how the dish room was currently operating during the early stages of the baseline testing. Once the baseline data acquisition equipment was installed, data was measured to determine two key performance characteristics: identify the major sources of water usage and determine the operation load in terms of meals served per day.

Performance Characteristic: Operational Loads in Meals Per Day

An important issue when comparing baseline with demonstration data was assuring the usage rates during these test periods were the same or about the same for the number of meals being served. A consistent number of meals served correlated to a similar number of racks being washed for each meal for daily, weekly and yearly time frames. Data was recorded for the total headcount for each day and divided up into breakfast, lunch and dinner for 6 months during the baseline testing. There were some variations in the headcount for different days of the week and due to DFAC closures but compared with other similar sized facilities the usage rate was very consistent on a weekly or greater timeframe basis. The average meals served per day was 984.

The consistent usage rate was expected to have a consistent water usage rate because the water usage rate per rack is the same for the dishwasher which is typical the largest water usage source in a DFAC. However, this was not the case as discussed in the Water Usage Profile section.

Performance Characteristic: Water Usage Profile

Water usage in a dishroom is not limited to the dish machine. Different water usage locations in the dishroom that were monitored during the project including the tank fill, rinse, pre rinse and sink. Data showed a significant water usage came from for pre-rinse which is done to remove food items and large stains on the dishware before entering the dish machine for cleaning and sanitation. Compared with the total water usage, the pre-rinse usage rate was higher than expected and lead to a deeper investigation of the water usage in the dish room besides the dish machine. Figure E3 showed significant variations for low and high water use. Most day use 1.5 to 1.7 gallons of water per meal to pre-rinse, but very significant numbers of days use less than 1 gallon and more than 3.4. The gap in the data from 2.8 to 3.5 shows that different methods were being used for the pre-rinse area.

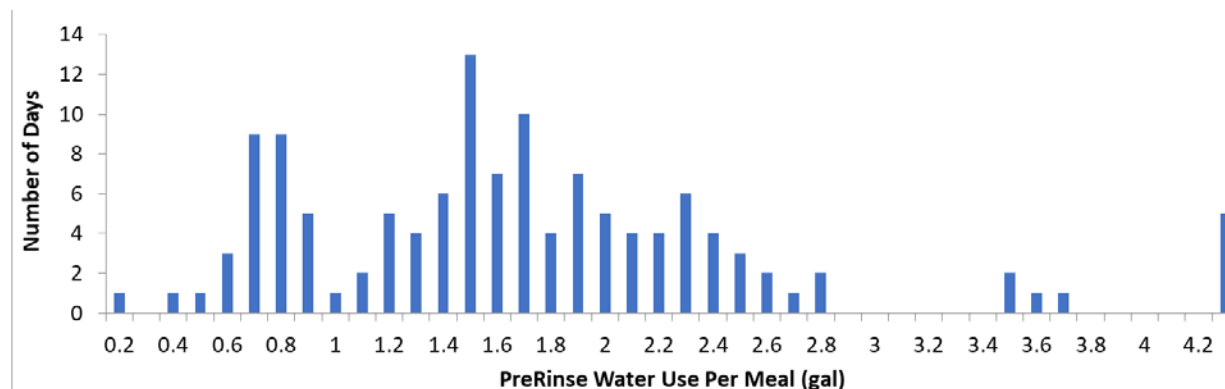


Figure E3. Water Usage for Pre-Rinse Area

The data showed that the variations in water usage were not a weekly or monthly trend but could occur on consecutive days. After discussions with the site energy manager and observations of dishroom operations over several days of dish washing, the problem was identified. A garden hose without a nozzle was being used to “wash out” the trough where the scraps collected below the pre-rinse station. On some days, the hose would be left on to continuously wash out the trough. The days with the hose left on were the data points for the PreRinse Water Use Per Meal that were greater than 3.5 gallons per meal. On a different day, a single employee was observed to only use the hose to rinse the trough periodically and was using a dry scrapping method to remove the excess food and stains from the dish ware. The water usage on these days were less than 1.0 gallons per meal as shown in Figure E3. After identifying this, the project team added a nozzle to the hose and recommended using a dry scrapping method to remove larger food items from the dishware. Information for pre-rinse operations was added to the Best Practices Guide for the project.

Quantitative Performance Objective: Water Heating Energy Usage

Once the water usage sources within the dishroom were identified, the baseline water usage was monitored for the total volume of water used and the energy required to heat the water for over 6 months. These values were compared with 6 months of water and energy data for the demonstration dish machine. In terms of energy use, the main difference from the baseline to the demonstration unit was that steam generated in the boiler room was the sole source of water heating for the DFAC including the dish machine and a natural gas booster heater was used as the primary heat source for the demonstration machine. The goal for the host site was to replace the steam boiler system with a natural gas system for dish washing and a smaller boiler for hot water in the sinks in the kitchen and bathrooms. During the demonstration, once the new dish machine and booster heater had established the ability to function as required, the larger boiler in the DFCA was decommissioned. Table E1 summarizes the energy usage for baseline operations and demonstration operations before and after decommissioning of the boiler system.

Table E1. Results for Energy Use for Dish Washing

Performance Objective	Baseline	Demonstration	Savings	Savings
Total Natural Gas Use	6.7 MMBtu/day	4.7 MMBtu/day	2.1 MMBtu/day	31%
		3.3 MMBtu/day*	3.5 MMBtu/day*	51%
Electricity (Conveyor, Pumps, Motor)	28 kWh/day	17 kWh/day	11 kWh/day	41%

As Table E1 shows, the use in natural gas in the DFAC was reduced by 31% once the new dish machine with the natural gas booster was put into operation. During the initial months of the demonstration, the natural gas boiler was still in operation for the hot water supply for the kitchen and bathroom sinks and heating. Eventually the large boiler was replaced with a smaller one because of the reduced capacity requirements. Once the boiler system was decommissioned, the total energy savings for water heating for washing dishes was reduced by 51%.

The goal was to achieve a 60% reduction in water heating energy usage and the project team has determined that if the existing boiler system in the DFAC was optimized for the new loads in the DFAC after the demonstration, that further savings could be achieved.

The original performance objective for energy use for water heating did not include energy associated with operating the baseline and demonstration dish machines, including electric motors to operate the conveyor, pump and motors. Table E1 shows that an additional 41% of electrical energy was saved using the demonstration dish machine. Combining the savings for the two energy types in Table E1, at total energy savings of 54% for replacing the baseline dish machine with the demonstration unit.

Waste Water Heat Recovery

The dish machine chosen for the demonstration had a built-in heat exchanger that uses the waste water to preheat the cold water at the inlet of the booster heater. External heat exchangers have been used over that past few years for applications including dish machines, showers, laundries and other waste hot water applications. The disadvantages of these types are clogging from grease or other matter in the waste stream and requiring addition floor space. For these reasons, the project used the Hobart dish machine with on-board heat recovery. This is first design of a commercial dish machine to include this technology. Data from the demonstration showed that the heat exchanger averaged a 42.4 °F increase in water temperature (63.2 °F to 105.6 °F). Based on the usage rates in gallons per day, the heat exchanger saved on average 2.2 therms (or 0.22 MMBtu) per day of natural gas energy. This equates to about 800 therms (or 80 MMBtu) per year or 10.4% percent of the total savings of energy for the heating of dish washing water.

Quantitative Performance Objective: Ventilation System Energy Usage

Past projects by Frontier Energy have shown that typically the ventilation systems in dishrooms are oversized and remove excessive room air from the dishroom and pulls conditioned air from other parts of the facility. The objective for this project was to resize the fan for the ventilation system to properly vent the dishroom to maintain a comfortable work environment and minimize the loss conditioned air. However, as identified early in the baseline testing, the existing ventilation system was undersized and not properly venting heat and humidity. The baseline carousel machine used a snorkel hood on the exit of the dish machine. This style of hood is effective on removing heat and moisture at the exit of the machine but does not capture heat and moisture within the dishroom. This would not be a problem if all the heat and moisture were being generated at only the exit of the machine. However, significant heat is added to the work space by the heated steam lines to the dish machine, leaks in the steam line and directly from the outer shell of the dish machine that heats up during operation. Also, moisture is added to the work space from the cleaned dishware once it exits the machine, the steam leaks and other processes in the dish room such as cleaning the floor or pre-rinsing. The demonstration conveyor machine is designed to work with a standard hood that is open over the entire machine including the inlet, outlet and pre-rinse area. This style of hood is much more effective on removing heat and moisture from the dish room to maintain a comfortable working environment. However; this style requires a higher ventilation rate with the same or more fan power than the baseline. Because of this change in hood design, there were no savings on the project by properly sizing the ventilation system.

Quantitative Performance Objective: Space Conditioning Energy Usage

Because of the change in the hood system design, there was not a reduction in ventilation rate from the baseline. Because of this, the volume of conditioned air from other parts of the facility being ventilated did not change from the baseline to the demonstration.

Quantitative Performance Objective: Water Usage

As detailed in earlier sections, there were many sources of water usage in the dishroom besides just the dish machine. Before the start of the project, it was expected almost all the savings would be from the dish machine with a performance objective of saving 75%. However, additional water savings was achieved by making changes on how dishes were pre-rinsed. These changes included using a low flow water nozzle, dry scrapping and minimizing rinsing of the food scraps trough. Table E2 list the water savings for only the dish machine and for the entire dish room, including the pre-rinse station. Replacing the baseline carousel dish machine with the demonstration conveyor dish machine saved approximately 89% of water usage or 5,185 gallons per day. Most of the savings is due to the newer machine using much less water to wash a single rack of dishware. However, additional water savings was realized because the design of the baseline carousel machine would allow a cleaned rack to go back through the machine agin if not removed once it exited the machine. The demonstration conveyor machine is a once through machine preventing racks from being rewashed. An additional 1,190 gallons per day were saved due to the changes in the operation of the pre-rinse area. The total savings of 6,375 gallons per day equates to approximately 2.33 million gallons of water saved per year in the DFAC.

Table E2. Results for Water Use for Dish Washing

Performance Objective	Baseline	Demonstration	Savings	Savings
Total Water Usage of Dish Machine	5,805 gal/day	620 gal/day	5,185 gal/day	89%
Total Water Usage of Dishroom	7,587 gal/day	1,212 gal/day	6,375 gal/day	84%

Quantitative Performance Objective: Dish Machine Reliability

The key parameters for reliability is hours of operation and the rinse temperature. The demonstration has operated for over one year at the time of this report with the only issues being with adjustments to the conveyor system and ventilation hood. The dish machine itself has cleaned dishes and utensils as required by the Tri-Service Food Code TB MED 530 in terms of appearance. The Tri-Service Food Code also sets a requirement for the rinse water temperature to be at least 160 °F to ensure dishware is properly sanitized.

Qualitative Performance Objective: User Satisfaction in Terms of Thermal Comfort of Working Environment

The dishroom in a DFAC or any other foodservice facility is generally the most difficult and uncomfortable area to work in because of the heat and humidity generated by the dish machine.

A properly size ventilation system removes heat and moisture from the dishroom to maintain a relatively comfortable work environment. After the installation of the demonstration equipment, energy site manager expressed that the work environment was significantly improved with less visible water on the floor. Baseline data showed a consistent 10 degrees increase in temperature and 7% increase in relative humidity due to heat and humidity from the dish machine during operation. Data for the demonstration machine showed that the temperature and humidity in room did not increase as much as with the baseline unit, thus confirming improved thermal comfort.

Qualitative Performance Objective: User Satisfaction in Terms of Cleaning Performance

According to Tri-Service Food Code TB MED 530, all dishware must be visibly clean and sanitized. The rinse water temperature was measured be at least 160 °F during the demonstration showing that the dishware was properly sanitized. Visual inspection of the dishware also meets with the requirements of the Tri-Service Food Code.

COST ASSESSMENT

The cost assessment for the replacement of an existing dish machine with an energy and water savings unit depends on the type of machine being replaced. As for this project, the existing machine was a carousel type that required a new dish room layout, conveyor feed system, energy supply and hood to be replaced with a conveyor dish machine. This type of replacement is more expensive compared to replacing an older machine with the same type of machine i.e. conveyor, door or flight.

The cost elements for implementing the change for an older carousel style dish machine to an energy efficient conveyor are listed in Table E3. The capital costs include the cost of the dish machine from Hobart, the gas booster from Hubbell, installation of natural gas supply line and changes to the pre-rinse station, dish table and conveyor system to accommodate the new machine. The last three would not be required if the baseline and demonstration dish machine were the same type. Installation costs include installation of the dish machine and the cost of the kitchen consultant. A kitchen consultant was needed for this project because of the extensive changes needed for the new layout of dishroom due to changing to a conveyor machine. Consumables include the cost of compostable dishware that was used to serve meals on because the DFAC had to stay in operation during the installation. The estimated cost of \$8,000 per year for washing detergent is based on the demonstration and other dish machine projects. Because the baseline and demonstration machines are high temperature units using hot water to sanitized dishes, chemical for sanitization are not needed. The table includes an estimated cost for training of the staff on how the operations of the dish room will need to change for a new conveyor unit. As discussed in the Best Practices Guide for this project, the project team strongly suggests doing this during the baseline testing or before the installation of a new dish machine. Another cost is recommended annual maintenance including having qualified technicians perform an inspection and do tasks such as clean the filters, remove scale from heating elements and replace seals if needed.

Table E3. Cost Model for an Energy Efficiency Dish Machine (Carousel to Conveyor)

Cost Element	Data Tracked During the Demonstration	Estimated Costs
Hardware capital costs	Dish Machine, Booster Heater, Hood, Conveyor, Pre-Rinse Station, Dish Table, Gas Line	\$77,302
Installation costs	Kitchen Consultant, Dish Machine	\$32,603
Consumables	Compostable Dishware: used during installation to keep DFAC operational	\$16,000
	Dish Washing Detergent: \$/year	\$8,000
Facility operational costs	Reduction in energy required vs. baseline data	\$14,248
	Reduction in water required vs. baseline data	\$46,537
Maintenance	Frequency of required maintenance	yearly
	Labor and material per maintenance action	\$500
Hardware lifetime	Estimate based on components degradation during demonstration	20 years
Operator training	Estimate of training costs	\$2,500

The cost model would change significantly if the baseline dish machine is the same type as the replacement. Cost elements like changes to the dish room layout and hood, operator training, installation and kitchen consultant would not be needed or greatly reduced. Also, if the facility can be shut down during the installation, replacement dishware would not be needed. The total cost difference between replacing a carousel with a conveyor and a carousel with a conveyor is estimated to be \$54,572 or 27% less. An equal amount of savings (9% each) is from the difference in hardware and installation costs. Consumables (dishware used during installation) saves about 4% and training saves about 1%. Thus, most of the cost is associated with installation costs from changing to a new type of machine, including hiring a consultant to redo the dish room layout.

Lifetime costs are presented in Table E4. Equipment & Installation Costs includes costs of buying the equipment, purchasing compostable dishware to use during installation, installing a new hood, modifying the pre-rinse station, modifying the dish table and conveyor, adding a gas line and hiring a kitchen consultant. Yearly Costs include cost of cleaning chemicals, maintenance, energy (gas and electric) and water. The natural gas savings includes approximately 800 therms of energy saved by the heat exchanger. The table also includes estimations for lifetime costs if the baseline carousel dish machine was replaced with a new machine of similar design. The estimates for equipment and installation costs are based from information from the kitchen consultant for the project. The only costs in the table that would vary based on location is the energy costs in the Yearly Costs. Compared to the energy costs in the region of California for the demonstration site, rates are generally 10-15% less expensive in the northeast US, 20-25% less expensive in the southeast and Midwest and 25-30% less expensive in Texas.

Table E4. Replacement Dish Machine Lifetime Costs

Installation Type	Equipment & Installation Costs	Yearly Costs	Expected Equipment Operational Life	Lifetime Cost
New Machine w/ Extensive Layout Changes	\$128,405	\$31,208	20 years	\$3,192,260
New Machine w/ Same Layout	\$73,833	\$31,208	20 years	\$2,100,820
Baseline Machine	\$150,000	\$91,993	20 years	\$4,839,860

Values from the new machine resulted in about \$14,000 per year for energy savings (therms of natural gas and kWh of electricity) and \$46,500 per year in water savings. Labor costs should did not change from the baseline to the demonstration machine except for the cost of training the staff on using the new type of machine in a new dish room layout.

IMPLEMENTATION ISSUES

The Presidio at Monterey was not required to acquire traditional building permits, but the proposed design of the dishroom for the demonstration with the new equipment was reviewed and approved internally to follow the required codes. All construction and installation activities were following local codes mandated by the City of Monterey Office of Plans and Public Works, thus any future sites should consult with local codes officials during the planning stages.

For installation in other DFAC locations, other various military codes that may apply include: Whole Building Design Guide (Section 11 48 00, Cleaning and Disposal Equipment for proper installation and operation) and the Tri-Service Food Code TM MED 350 (Construction and Installation section of Chapters 4, 5 and 6).

Because the basic methodology of operating the dish machine was not going to change from the baseline to the new machine, a kitchen designer was not used during the early stages of the project. The plan was to place a new machine into the existing footprint of the old machine and use the same conveyor system to move trays from the drop off location to the pre-rinse station to the dish machine. However, as the baseline testing was coming to an end, it was determined that existing layout of the dishroom and the location of the hoods would not work with the new machine. Also, the pre-rinse station needed to be relocated. After working with the site energy manager and existing staff, it was determined an experienced kitchen designer was needed to meet the needs of the sites, incorporate new plans of the usage of the dishroom and to determine the dish machine and hood location. If a designer had been used in the early stages of the project, several issues and delays could have been avoided. The team eventually hired the original designer of the facility to assist with the new layout. Based on this experience, it is highly recommended before doing any changes to a dishroom to hire an experienced DFAC kitchen designer.

Another learned lesson was to use an experienced and local installer if possible. Several delays to the project occurred because the nearest installer was located over an hour away from the site. There also were issues with the installer on getting to site and determining the correct location of the new equipment in the site. Including a kitchen designer in the early stages would have helped. The Best Practices Guide for this project further details some of the installation issues for this project.

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1.0 INTRODUCTION

1.1 BACKGROUND

Energy and water usage for commercial foodservice have a significant impact on the overall usage of a facility. Daily meal preparation and cleanup in a military dining facility (DFAC) represents more than 75% of the energy and water load in the facility. Within the foodservice facility itself, the dishwashing room or “dishroom” has the highest energy intensity compared to the other zones within a DFAC (ASHRAE, 2012). The dishroom has an intensity of 53.5 W/ft², compared to 29.3 W/ft² for the Carry Out zone, 27.1 W/ft² for the Server zone and 13.5 W/ft² for the Kitchen zone. Up to 75% of the hot water in the kitchen is consumed in the dishroom. Many of the dishwashers installed in foodservice facilities and DFACs are older, use excessive volumes of hot water and are being operated inefficiently. Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dishwashers with modern ENERGY STAR® qualified models. Recent findings have shown that not only are these existing dishwashers (also called warewashers or dish machines) consuming large volumes of hot water for the rinse operation, but also the staff operating practices are greatly adding to additional water waste. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy (formally known as Fisher Nickel, Inc). While energy-efficient cooking equipment, improved ventilation systems and advanced space conditions systems have been developed and used for the kitchen, dining, and serving zones; the dishroom has experienced fewer improvements in energy and water usage for all types of foodservice facilities including DFACs.

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of this project is to identify and demonstrate a comprehensive strategy of installing and analyzing new technologies to reduce the energy and water usage and energy intensity within a dishroom at a military installation used for cleaning and sanitizing of flatware, dishes, cooking vessels and other foodservice related utensils. Included are technologies to recover heat from waste water, to reduce waste water, to improve worker environmental conditions, to demonstrate reliability and to reduce space conditioning loads. The specific Performance Objectives were: 60% energy savings for heating water to the dishwasher, 30% energy savings for the ventilation system including fan power and energy to condition indoor air and 75% savings for water for washing. The results of this project were used for a Best Practices Guide and workshop presentation to assist energy managers, consultants and commercial foodservice contractors at DoD locations to recognize the benefits of the dishroom technologies demonstrated. The ventilation results were used as the basis for establishing dishroom ventilation standards that do not exist for any foodservice applications.

1.3 REGULATORY DRIVERS

Because of the energy and water savings potential and ventilation improvements of the technologies in this project, several current, existing or anticipated regulations, Executive Order, directives, industry standards or other drives will be addressed. These include the following:

- Executive Order (EO) 13423, "Strengthening Federal Environmental, Energy, and Transportation Management,"
 - The project will address energy efficiency and sustainable building management
- Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance,"
 - Expands EO 13423
 - Reduction of petroleum consumption and potable water intensity by 2% per year through FY2020
 - Reduction of building energy intensity by 2% per year through FY2020
 - Management strategies to improve sustainability
- Energy Policy Act of 2005
 - Sec 131 Energy Star program
 - The project will provide data to support Energy Star standards for commercial dish machines
 - Sec 136 Energy conservation standard for commercial equipment
 - The project will provide data to support energy conservation standards for commercial dish machines
- Energy Independence and Security Act of 2007
 - Sec. 421 Commercial high-performance green buildings
- Federal Leadership in High Performance and Sustainable Buildings MOU 2006
 - Improve energy efficiency (20% for major renovations) and water conservation (20%)
 - The project will provide data for energy savings and water conservation for the demonstration technologies
 - Enhance Indoor Environmental Quality – Ventilation and Thermal Comfort, Meet the current ASHRAE Standard 55-2004
 - The project will provide data for the improvement of thermal comfort in the dish room from the use of the improved ventilation system
- Strategic Sustainability Performance Plan
 - Sub-Goal 1.1 Energy Intensity of Facilities Reduced by 30% from FY 2003 by FY 2015 and 37.5% by FY 2020
 - The project will provide data for energy savings for the demonstration technologies
 - Sub-Goal 2.1 Potable Water Consumption Intensity by Facilities Reduced by 26% from FY 2007 by FY 2020

- The project will provide data for water conservation for the demonstration technologies
- Energy Security MOU with DOE
 - Support projects aimed at improving energy efficiency and renewable efforts across the military services
 - The project supports this effort by demonstration improved energy efficiency and water conservation
- Whole Building Design Guide
 - Compliance with Section 11 48 00, Cleaning and Disposal Equipment for proper installation and operation
 - The project will demonstration the cleaning and sanitation abilities of the technologies in compliance with this guide
- Tri-Service Food Code TM MED 350:
 - The project will demonstration the cleaning and sanitation abilities of the technologies in compliance with this code
- ASHRAE
 - The project will provide data and a white paper to support TC 5.10 for establishing ventilation guidelines in commercial foodservice operations
- Energy Star®
 - New units on average 40% more energy efficient and 40% less water
 - The project will provide data and information to support existing and development of new Energy Star standard for commercial dish machines

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2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

To achieve the objective of reducing energy and water usage in dishroom installations, the project team led by Gas Technology Institute (GTI) demonstrated three types of technologies: waste water heat recovery, optimized ventilation system and a low-water usage warewasher or dish machine. An optimal savings potential can be achieved from the three technologies based on the interrelationship between them. The dish machine cleans dishware and other items producing steam and hot waste water at various rates depending on the load sizes. The ventilation system vents the steam produced by the dish machine but is typically not set to ventilate at the correct rate to ensure an optimal working environment in terms of comfort. A waste water recovery system reuses heat from the waste water to preheat inlet water to the dish machine that would otherwise be literally poured down the drain. By recovering waste heat and adjusting the ventilation rate, less energy and water is used to clean the dishes and to maintain a comfortable work environment.

Because of the elevated temperatures required for washing and rinsing in dish machines during continuous operation, hundreds of gallons of 140 °F to 160 °F water are dumped down the drain. Some regions legislate a maximum water temperature that can be put into sanitary drains, thus additional cold water is mixed in to cool the discharge from the dish machine. At the start of this project, two technologies existed to recover the heat from the drain. The Gravity-Film Heat Exchanger (GFX) is a vertical counterflow heat exchanger to transfer heat from the drain water to the incoming water of the dishwasher, see **Figure 1**. Waste water flows through a 2 to 4 inch central copper pipe with a ½ inch copper coil wrapped around it and is the supply line to the dish machine. The coils are slightly flattened to increase surface area and thus improve heat transfer.



Figure 1. GFX Schematic

The other technology was the Novothermic NVX2060 Heat Exchanger, shown in **Figure 2**. This unit is also a heat exchanger for transferring heat from the drain to the supply water of the dishwasher. Estimates from the manufacturer show the system could save from 30% to 50% of the heating energy for the dishwasher with 2 to 5 years pay back on the technology based on the installations usage rate and climate. The is a standalone unit positioned next to or underneath the washer and requires a power source. After an initial evaluation of the proposed demonstration site at US Army Garrison Presidio of Monterey, the Novothermic was the leading candidate based on the type of warewasher and the layout of the dish room.



Figure 2. Novothermic NVX2060

During the baseline testing, a new dish machine manufactured by Hobart became available that had built in heat recovery. The Hobart CLPS86ER is a conveyor style dish machine that has an internal heat exchanger for recovering heat from the waste water to reuse for heating new wash water. A link to the specification sheet for this unit is given in the reference section of this report and the specification sheet is included in the appendix. After discussions with the manufacturer and host site, the project team requested and was granted a change of scope to switch to this unit. The advantages of on-board vs. external heat recovery are technical support would be consolidated with a single manufacturer for both the heat recovery unit and the dish machine and additional floor space in the already tight dish room would not be needed for an external unit.



Figure 3. Hobart CLPS86ER Conveyor Dish Machine

In accordance with ASTM F1920, Standard Test Method for Performance of Rack Conveyor, Commercial Dishwashing Machines with canopy exhaust, hoods shall use a 3 foot by 6-foot configuration for operating at the dishwashing machine manufacturer's specified ventilation rate. Because the fan on the exhaust is capable of only one speed and thus one flow rate, the rate is typically set to maintain an ambient temperature of $75^{\circ}\text{F} \pm 5^{\circ}\text{F}$ for the maximum capacity of the dishwasher. Typically, the exhaust hood is set too high for the ventilation rate resulting more air being removed from the dishroom and pulling excess air from the rest of DFAC. This results in energy being wasted because the excess air typically has been heated or air-conditioned for the comfort of the occupants.

Warewashers or dish machines are available in three designs for the washing and sanitizing of items including plates, eating utensils, and cooking utensils: flight type, rack conveyor and stationary door. The designs vary for cleaning volumes and cleaning rates.

Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dishwashers with modern ENERGY STAR® qualified models. Recent findings have shown that not only are these existing dishwashers consuming large volumes of hot water for the rinse operation, but also the staff operating practices are greatly adding to additional water waste. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy. The most common design for dish machine is the use of electric heating elements to heat the water. Despite a majority of most commercial foodservice appliance types using natural gas as the fuel source, dish machines are over 95% electric. The main reason is electric dish machines are easier to design and manufacture because there is limited space available within the confines of the unit for positioning a gas-fired water heating system including a burner, tank, gas train and vent. In the early 1990's, gas-fired units were introduced to the market, reaching a 20% market penetration. However, limitations with the gas-fired burner designs of that time resulted in reliability issues, especially ignition problems leading manufactures to discontinue selling gas-fired units. The current state of the art for natural gas dish machines is to use an external gas-fired booster heater to preheat the water to a dish machine with an electrical heating element to heat the water to the final rinsing and washing temperatures. During the baseline testing phase, the required capacity for dish washing was determined for the US Army Garrison Presidio of Monterey and the Hobart CLPS86ER (**Figure 3**) with an internal heat exchanger was chosen for the demonstration.

2.2 TECHNOLOGY DEVELOPMENT

Technology development for the basic design of the dish machine, booster water heater and ventilation system were all done before the start of the project and included in the proposal and demonstration plan. The only new development was the addition of an on-board heater exchanger for the waste water. This technology development was done independently by Hobart but made aware to the project team during the baseline for consideration in use in this project. After discussions with Hobart and the host site, the project team requested and was granted a change of scope to switch to the Hobart unit.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The technologies for this project are at various stages of development and deployment. The GFX technology was developed over ten years ago and evaluated by Oak Ridge National Laboratory (Tomlinson, 2000), but a commercial unit is not yet available. The Novothermic NVX-2060 was just made commercially available but has not achieved a significant market penetration. The model considered for use in the project was evaluated by Frontier Energy at their test facility. During the baseline phase of the project, issues arose with the availability for technical support from the manufacturer for the Novothermic and a unit from Hobart with on-board heat exchange became available. After discussions with Hobart and the host site, the project team requested and was granted a change of scope to switch to the Hobart unit. Advantages of using on-board heat exchange include reduced floor space for equipment and consolidated technical support for both the heat exchanger and dish machine.

Hood ventilation systems are commercially available and have been proven with the cook line for commercial foodservice facilities but have not been tested and optimized for use in dishrooms. Gas-fired dish machines were commercially available over ten years ago but discontinued because of burner reliability issues. A reliable burner system design was developed by GTI as part of a two-year \$140,000 project funded by the natural gas industry. The unit was field demonstrated during this project and the combustion system shown to work reliably. However, the manufacturing partner chose not to proceed to production. GTI is currently conducting a market evaluation for gas-fired dish machines and in discussions with another manufacturer. Because of the preference of the site to use natural gas as the primary heat source, the Hobart unit was paired with an external natural gas booster heater from Hubbell. The unit pre-heats the inlet water to the dish machine to almost the temperature required for rinsing and washing. An on-board electric heater provides a small amount of energy to reach the final water temperatures.

3.0 PERFORMANCE OBJECTIVES

The demonstration included the testing and evaluation of individual units; including a new dish machine, ventilation system and heat recovery system. Each unit has separate performance objectives that were tested during the demonstration.

Table 1. Performance Objectives and Results for Energy and Water Efficiency Improvements for Dishrooms in Military Dining Facilities (Project EW201518)

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Water Heating Energy Usage	Energy (MMBtu)	Meter readings of energy used by water heating system supplying the dish machine; operation hours of dish machine	60% reduction compared to baseline	51% reduction compared to baseline**
Ventilation System Energy Usage	Fan Power Energy (kWh)	Meter readings of energy used by fan for ventilation system	30% combined reduction compared to baseline while maintaining the appropriate interior conditions	Unable to reduce fan power or save space conditioning energy because original ventilation was undersized and ineffective
Space Conditioning Energy Usage	Space Conditioning System Energy (kWh, MMBtu)	Meter readings of energy used to condition air space in dishroom; Temperature (outdoor, dishroom) and Humidity (outdoor, dishroom)		
Water Usage	Water (Gallons)	Meter reading of volume of water used by dish machine	75% reduction compared to baseline	89% reduction compared to baseline
System Simple Payback	Cost Savings (\$)	Energy and water usage and costs. Equipment and O&M costs	Confirmation that simple payback is less than 5 years	27 months
Dish Machine Reliability	Operation Time (hrs)	Operation curves for the water temperature showing the gas-fired heat source provided the required heat without failure	Confirmation that the dish machine heat source operated without failure	Confirmed
Qualitative Performance Objectives				
User Satisfaction in Terms of Thermal Comfort of Working Environment	Degree of Satisfaction	Scale Survey	15% Increase in satisfaction over baseline	Confirmed by survey of site energy manager
User Satisfaction in Terms of Cleaning Performance	Degree of Satisfaction	Scale Survey Images of the cleaned dishware	Maintains or improves cleaning of dishware, Compliance with Tri-Service Food Code TM MED 350	Confirmed by onsite inspection and images

** Did not meet desired savings due to extenuating circumstances detailed in Water Heater Energy Usage section below and in Section 6.3

Below is a detailed description of the Performance Objectives for both the individual and combined units in the demonstration from

Table 1 and as approved in the project Demonstration Plan. An explanation of the results has been added in for this report.

Water Heating Energy Usage

- Purpose: The energy usage of the dish machine is relevant to the success of the demonstration by showing both a reduction in energy used to heat the water and a reduction in the volume of the water used to clean and sanitize dishware in the DFAC.
- Metric: Most heating for dishroom machines is accomplished through energy from combustion of natural gas in MMBtu. The efficiency of heating water will not significantly improve, but the total energy for heating will decrease because of the reduced water usage of the new dish machine that will be installed during the demonstration.
- Data: The data will be volume of natural gas acquired using gas meters with pulse outputs. The volume in cubic meters will be equated to MMBtu.
- Analytical Methodology: The data will be compared in tabular form with graphs showing typical energy usage over weekly periods for both baseline and new demonstration dish machine.
- Success Criteria: A 60% reduction in energy for heating water from the baseline unit compared to the new demonstration dish machine.
- Results: Once the boiler system was decommissioned, the total energy savings for water heating for washing dishes was reduced by 51%. The goal was to achieve a 60% reduction in water heating energy usage and the project team has determined that if the existing boiler system in the DFAC was optimized for the new loads in the DFAC after the demonstration, that further savings could be achieved.

Ventilation System Energy Usage (VSE) & Space Condition Energy Usage (SCE)

- Purpose: The performance objective of the ventilation system will combine data for the energy use of the system and the space condition system. Each have their own data set but the energy savings from each will be combined into a single value.
 - VSE: The energy usage of the ventilation system in the dishroom is relevant as a measure of the energy required by code to properly vent the dishroom of heat and steam, making for a comfortable work environment in the DFAC. The energy readings will show that a smaller volume of dishroom air can be ventilated to meet code and comfort requirements while using less energy to run the ventilation fan and reducing the loss of air that has already been conditioned by the DFAC space conditioning system.

- SCE: The energy usage of the space conditioning system in the dishroom is relevant as a measure of the energy saved by minimizing the amount of conditioned air that is drawn into the ventilation system by optimizing the amount of air from the dishroom that must be ventilated to control the heat and humidity to make to a comfortable work environment.
- Metric:
 - VSE: By comparing the fan power readings (kWh) for the baseline and demonstration ventilation systems, energy savings and volume of air removed from the dishroom, total energy savings can be calculated.
 - SCE: By comparing the total energy used to condition the air in the DFAC (both electric and natural gas usage) for the baseline and demonstration, energy savings can be calculated.
- Data:
 - VSE: The data will be measured using an electric meter on the fan. Flowrate of ventilation air will be determined based on the measure the energy usage of the fan the fan power flow curve provided by the manufacturer.
 - SCE: Electrical energy (kWh) will be measured using an electric meter and natural gas usage will be measured using gas meters with pulse outputs. The volume in cubic meters will be equated to MMBtu. Interior temperature and humidity will be measured using remote data loggers with built in thermocouples and hygrometers.
- Analytical Methodology:
 - VSE: The data will be compared in tabular form with graphs showing typical energy usage over weekly periods for both baseline and new demonstration dish machine.
 - SCE: The energy savings will be calculated using the Outdoor Airload Calculator (OAC), a web-based tool developed by the Fisher-Nickel, Inc (available at <http://www.fishnick.com/ventilation/oalc/oac.php>). The tool generates models of the annual heating load in kBtu based on ASHRAE weather data accessed by the calculator. The data will be compared in tabular form with graphs showing typical energy usage over weekly periods for both baseline and new demonstration dish machine. Because the data taken will be for less than a calendar year and because outdoor conditions vary throughout the year and from year to year, the tool will also be used to extrapolate the measured data to calculate energy savings for yearly basis and for potential savings at other locations.
- Success Criteria: A combined energy savings of 30% for the ventilation and space conditioning systems.
- Results: Unable to reduce fan power or save space conditioning energy because original ventilation was undersized and ineffective. A detailed explanation is given in section 6.4 and 6.5.

Water Usage

- Purpose: The water usage of the dish machine is relevant to the success of the demonstration by showing both a reduction in the volume of water used to clean and sanitize dishware in the DFAC and a corresponding reduction in energy used to heat the water.
- Metric: For this demonstration, the efficiency of heating water will not significantly improve, but the total energy for heating will decrease because of the reduced water usage of the new dish machine that will be installed during the demonstration.
- Data: The water usage will be measured in gallons using standard water meters installed on the water lines to the dish machine.
- Analytical Methodology: The data will be compared in tabular form with graphs showing typical water usage over weekly periods for both baseline and the new demonstration dish machine.
- Success Criteria: A 75% reduction in water usage from the baseline unit compared to the new demonstration dish machine.
- Results: Replacing the baseline carousel dish machine with the demonstration conveyor dish machine saved approximately 89% of water usage or 5,185 gallons per day. Most of the savings is due to the newer machine using much less water to wash a single rack of dishware. However, additional water savings was realized because the design of the baseline carousel machine would allow a cleaned rack to go back through the machine if not removed once it exited the machine. The demonstration conveyor machine is a once through machine preventing racks from being rewashed. An additional 1,190 gallons per day were saved due to the changes in the operation of the pre-rinse area discussed in section 6.2. The total savings of 6,375 gallons per day equates to approximately 2.33 million gallons of water saved per year in the DFAC.

System Simple Payback

- Purpose: The simple payback of the dish machine is relevant to the success of the demonstration by showing that the costs of installing the new equipment is less than the savings that is incurred over the life of the equipment. Because the energy and water savings of the new dish machine, ventilation system and heat recovery unit is expected to be significant, simple payback is expected to be attractive for installing the new system.
- Metric: For this demonstration, the simple payback is calculated by dividing the total purchase and installation cost of the new system divided by the annual energy and water savings associated with the new system.
- Data: Energy and water usage and costs. Equipment and O&M costs
- Analytical Methodology: The costs of using the new system including energy, water, O&M and equipment will be calculated based on usage and/or purchase costs and used to determine the simple payback of the new system.

- Success Criteria: The calculation of a simple payback to be used as the basis for installing a similar system at other DFAC locations.
- Results: Based on the equipment and installation costs from the demonstration of \$136,405 and total yearly cost savings of 60,786, the system simple payback is 2.24 years or about 27 months. A detailed cost assessment is given section 7.0.

Dish Machine Reliability

- Purpose: The reliability of the gas-fired heating source of the dish machine is important to show that new machines can operate without failure and perform more reliably than previous designs.
- Metric: For this demonstration, the reliability of the gas-fired combustion system will be shown in operation curves for the water temperature of the unit. The curves will show that whenever the unit called for heat, the combustion system responded as specified.
- Data: Operation curves for the hot water temperature in the dish machine
- Analytical Methodology: The reliability of the gas-fired combustion heating system will be shown in the operation curves. The curves should show the same heat up time and temperature changes as function of time for each time the unit calls for heat.
- Success Criteria: Confirmation that gas-fired combustion system provided the required change in water temperature for each cycle over the entire 6-month demonstration period.
- Results: The demonstration dish machine has operated for over one year at the time of this report with the only issues being with adjustments to the conveyor system and ventilation hood. The dish machine cleaned dishes and utensils as required by the Tri-Service Food Code TB MED 530 in terms of appearance. The Tri-Service Food Code also sets a requirement for the rinse water temperature to be at least 160 °F to ensure dishware is properly sanitized. The rinse water temperature was measured be at least 160 °F for over 227 days during the demonstration and at no time was it recorded to be less than 160 °F. For some days during the demonstration, the rinse water temperature was not recorded due to measurement equipment issues.

User Satisfaction in Terms of Thermal Comfort of Working Environment

- Purpose: To determine that the new equipment installed for the demonstration improves the working environment in terms of thermal comfort for the persons working in the DFAC.
- Metric: Thermal comfort is a function of both temperature and humidity, which will be monitored. But the metric used to measure success will be a satisfaction survey in terms of thermal comfort completed by persons working in the DFAC dishroom. The survey will be based on previous comfort surveys completed by Fisher-Nickel and will administer with the assistance of the site energy manager and the company contracted to operate the facility. The results will be compared to the measured values of temperature and humidity in the dishroom and the ASHRAE standards for human comfort based on temperature and humidity.

- Data: A scale based survey will be used during baseline and demonstration testing to gauge the comfort levels of persons working in the DFAC dishroom. Actual room temperature and humidity levels for both baseline and demonstration testing will be measured and evaluated.
- Analytical Methodology: Survey results will be compared in tabular form with statistical analysis applied, including margin of error and range of data.
- Success Criteria: A 15% increase in thermal comfort satisfaction for baseline vs. demonstration.
- Result: A survey of the energy site manager confirmed that the work environment was significantly improved in terms of temperature and humidity with less visible water on the floor. A detailed analysis of thermal comfort is given in section 6.9 of this report

User Satisfaction in Terms of Cleaning Performance

- Purpose: To determine that the new equipment installed for the demonstration maintains or improves the cleaning performance of the dishware when comparing the existing machine with the new demonstration unit.
- Metric: The metric used to measure success will be a satisfaction survey completed by persons working in the DFAC dishroom and compliance to the cleaning and sanitization codes in paragraphs 4-6 and 4-7 of the Tri-Service Food Code TB MED 530. This includes, but not limited to, visible removal of all grease and soil accumulations and achieving a surface temperature of 160 °F.
- Data: A scale based survey will be used during baseline and demonstration testing to gauge the performance of the dish machine in terms of its ability to clean dishware. Images of cleaned dishware for both the baseline and demonstration testing will be taken.
- Analytical Methodology: Survey results will be compared in tabular form with statistical analysis applied, including margin of error and range of data. The survey questions will be based on the cleaning and sanitization codes in TB MED 530.
- Success Criteria: Maintain or improve the cleaning of the dishware for the demonstration unit compared to the baseline or existing unit and complying to TB MED 530
- Results: An image in section 6.10 of this report shows the dishware to be in compliance in terms of visible cleanliness. Measurements of the rinse water also confirm that the dishware was properly sanitized.

4.0 FACILITY/SITE DESCRIPTION

4.1 FACILITY/SITE LOCATION AND OPERATIONS

The demonstration was conducted at the US Army Garrison Presidio of Monterey located in Monterey, CA. The Presidio of Monterey provides professional base support services to facilitate mission readiness and promote wellbeing for all supported elements. The primary tenant organization is the Defense Language Institute Foreign Language Center (DLIFLC). DLIFLC provides foreign language education, training, evaluation and sustainment for DoD personnel to ensure the success of the Defense Foreign Language Program and enhance the security of the Nation. The present facilities at the Presidio of Monterey accommodate approximately 3,500 Soldiers, Marines, Sailors and Airmen, as well as select DoD members and the U.S. Coast Guard. The base has two active DFACs with Belas Hall chosen for the demonstration. During the proposal stages, project team visited the Presidio of Monterey and determined the type of dishroom equipment used and determined that the layout of the dishroom in the Belas Hall was compatible with the objectives of the proposed project. Specifically, there was sufficient room to install a new dish machine with the heat recovery unit on the waste water drain and an existing ventilation system to be monitored and replaced. The project team worked with the DFAC staff to ensure the installation of data monitoring equipment and demonstration units do not interfere with the day-to-day operations of the facility. Jay Tulley, Energy Manage, served as the point of contact.



Figure 4. Belas Hall at US Army Garrison Presidio of Monterey

The DFAC is in Monterey, CA approximately 110 miles from Frontier Energy (formally known as Fisher-Nickel, Inc). This allowed Frontier team members to visit the site in a timely manner to retrieve data and address any issues when needed.

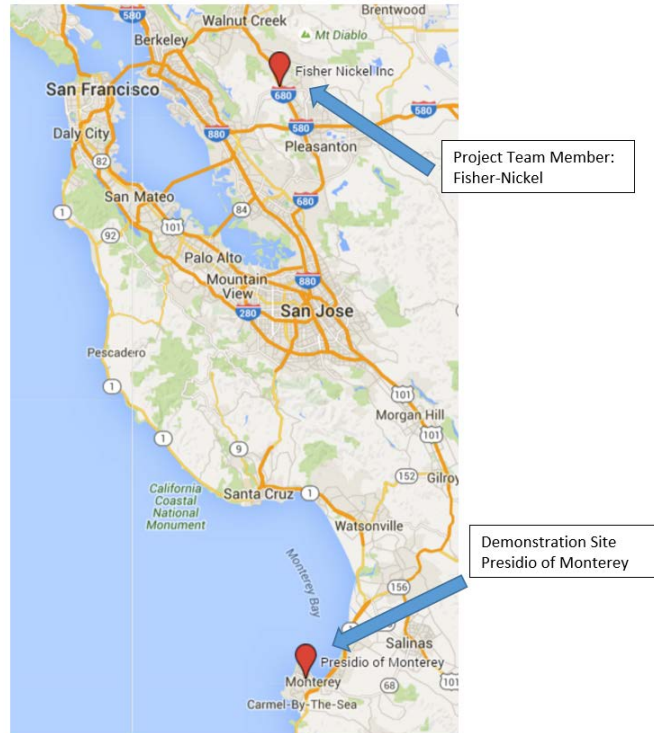


Figure 5. Map of Demonstration Site and Closest Project Team Member



Figure 6. Dish Room at Belas Hall

4.2 FACILITY/SITE CONDITIONS

The site selection for this project was based on three main criteria: layout of the dishroom proximity to project team and installation support. Because dishroom operations are not heavily influenced by environmental conditions, geographic location in terms of climate were not a criterion for the project.

The key consideration for choosing a site was the layout of the dishroom. Specifically, the layout needed to be like most DFAC dish rooms but with sufficient room to install a new dish machine with the heat recovery unit on the waste water drain and an existing ventilation system to be monitored and replaced. The facility also needed space for installation of data monitoring equipment such that it would not interfere with the day-to-day operations of the facility. Another consideration was location in proximity to a project team member. A requirement of the project was a data monitoring system that would acquire data locally without using connections via the internet or cellular system. By having the demonstration within 3 hours of a team member, the data was retrieved by a team member for analysis and was on site within a reasonable timeframe if any issues with the equipment of data monitoring system occurred.

The final criteria for selection was the installation support that would be provided by the host site. Specifically, the project team required assistance with:

- Determining baseline, conventional dishroom equipment performance
- Installing new dishroom equipment including dishwasher, ventilation hood and waste water heat recovery equipment
- Analyzing data from both baseline and new equipment installations
- Removing the monitoring equipment at the end of the project.

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5.0 TEST DESIGN

Energy and water usage for commercial foodservice have a significant impact on the overall usage of a facility. Daily meal preparation and cleanup in a military dining facility (DFAC) represents more than 75% of the energy and water load in the facility. Within the foodservice facility itself, the dishwashing room or “dishroom” has the highest energy intensity compared to the other zones within a DFAC (ASHRAE, 2012). The dishroom has an intensity of 53.5 W/ft², compared to 29.3 W/ft² for the Carry Out zone, 27.1 W/ft² for the Server zone, and 13.5 W/ft² for the Kitchen zone. Up to 75% of the hot water in the kitchen is consumed in the dishroom. Many of the dishwashers installed in foodservice facilities are older, use excessive volumes of hot water and are being operated inefficiently. Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dishwashers with modern ENERGY STAR® qualified models. Recent findings have shown that the existing dishwashers (also called warewashers) consuming large than needed volumes of hot water for the rinse operation. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy by using new dishroom technologies and implementing standard operation procedures. Most of the water savings comes from using the new equipment, but a small but significant volume can be saved by implementing standard operational procedures for the staff using the equipment.

While energy-efficient cooking equipment, improved ventilation systems and advanced space conditions systems have been developed and used for the kitchen, dining and serving zones; the dishroom has experienced fewer improvements in energy and water usage for all types of foodservice facilities including DFACs. The testing in this demonstration was designed to address this problem by generating the data and information needed to show that newer equipment can save significant energy and water. Other issues that were addressed showed the equipment can clean dishes as well as older technology while operating reliably.

5.1 CONCEPTUAL TEST DESIGN

This project was designed to show that the installation and optimization of new dishroom technologies can reduce the water consumption, energy usage and energy intensity within a dishroom at a military installation used for cleaning and sanitizing of flatware, dishes, cooking vessels and other foodservice related utensils while maintaining the cleaning performance. To accomplish this, changes to the DFAC included the removal of the existing dish machine and replacing with a new dish machine with heat recovery and ventilation system. The dish machine was similar in function as the old, but a used much less water and energy to clean. The heat recovery system captured heat that was previous discharged in the drain to preheat inlet water to the dish machine. The ventilation system replaced the old design with one optimized for the new dish machine that better captures and exhaust the required amounts of heat and steam from the dishroom.

The demonstration site was fully instrumented with data acquisition equipment to measure the water and energy usage of the dishwasher, pre-rinse area and ventilation system. Variables measured included but are not limited to: temperature (water and room), electrical energy, water flowrate, air flowrate, racks of dishes washed, natural gas usage, fan power and humidity.

The data was acquired using standard gas meters, electrical meters, thermocouples and hygrometers and controlled and recorded by a data acquisition system. The data acquisition equipment was installed so not to interfere with daily operation of the DFAC. For over six months, the existing equipment in the dishroom was monitored to establish a baseline water and energy usage. The specific variables to be measured for each aspect of the demonstration are:

Dish machine – natural gas usage, electric usage, water usage, water temperature (inlet and drain), dish rack cleaning rate

Ventilation – fan electrical energy, inlet temperature and humidity, fan flowrate

Dishroom and outdoor temperature and humidity were also monitored to measure comfort level.

Once the new technology was installed, the dishroom was monitored again for over six months to give an accurate comparison of the water and energy usage with the baseline equipment. Data collection was monitored by Frontier Energy and checked at least weekly to confirm the system was acquiring data as expected.

5.2 BASELINE CHARACTERIZATION

The objective was to fully demonstrate and quantify the energy and water savings of the proposed technologies and meet the Performance Objectives of 60% energy savings for heating water to the dishwasher, 30% energy savings for ventilation system including fan power and energy to condition indoor air and 75% savings for water for washing. To do that, the team first performed a baseline characterization of the existing system. The test design has been employed on previous projects by GTI and Frontier Energy.

The dishroom in the DFAC (Belas Hall) was fully instrumented with data acquisition equipment to measure the water and energy usage of the dishwasher, pre-rinse area and ventilation system. Variables measured include, but are not limited to, temperature (water and room), electrical energy, water flowrate, air flowrate, racks of dishes washed, natural gas usage, fan power, and humidity. The data was acquired using standard gas meters, electrical meters, thermocouples and hygrometers and controlled and recorded by a data acquisition system. The data acquisition equipment was installed so not to interfere with daily operation of the DFAC. Over six months, the existing equipment in the dishroom with monitored to establish a baseline water and energy usage.

Baseline collection began in February 2016 and continued for over 6 months. Because of the relatively consistent climate in Monterey, this time was sufficient to determine baseline energy use of the systems within the dishroom. Existing energy bills, operation times based on estimates from the base energy manager and listed energy usage rates of existing equipment were also used to estimate the baseline energy usage and provide energy rates.

Most the energy usage data was directly measured using water, gas and electrical meters. Because the supply air to the dishroom comes from transfer air from adjacent spaces and not a separate air supply or makeup air unit, the supply air flow volume will be assumed to equal the exhaust air flowrate in the vent or exhaust above the dish machine. The baseline exhaust air flow rate was measured with a duct velocity traverse on the exhaust side.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

The Presidio at Monterey was not required to acquire traditional building permits, but the proposed design of the dishroom for the demonstration with the new equipment was reviewed and approved internally to follow the required codes. All construction and installation activities followed local codes mandated by the City of Monterey Office of Plans and Public Works. The point of contact with the city was Andreas Baer, who was present at the project kickoff meeting and outlined how the city would be involved with the demonstration. The installation of the new equipment followed the various military codes including: Whole Building Design Guide (Section 11 48 00, Cleaning and Disposal Equipment for proper installation and operation) and the Tri-Service Food Code TM MED 350 (Construction and Installation section of Chapters 4, 5 and 6).

The initial plan for the project was to use a newer dish machine with an external heat recovery unit to capture waste heat from the water outlet. During the baseline testing of the existing dish machine at Belas Hall at US Army Garrison Presidio of Monterey, a new dish machine manufactured by Hobart became available that had built in heat recovery. The Hobart CLPS86ER is a conveyor style dish machine that has an internal heat exchanger for recovering heat from the waste water to reuse for heating new wash water. A link to the specification sheet for this unit is given in the reference section of this report. After discussions with the manufacturer and host site, the project team requested and was granted a change of scope to switch to this unit. The advantage of on-board vs. external heat recovery is technical support would be consolidated with a single manufacturer for both the heat recovery unit and the dish machine and additional floor space in the already tight dish room would not be needed for an external unit.



Figure 7. Hobart CLPS86ER Conveyor Dish Machine

The new dish machine uses natural gas as the primary fuel source in the form of gas booster heater for heating the water at the inlet of the machine. The booster heater chosen was the Hubbell PT56. The unit uses the patented VariFlame™ temperature control that saves energy by not using a standing pilot for burner ignition. A link to the specification sheet for this unit is given in the reference section of this report.



Figure 8. Hubbell PT56 Gas Booster Heater



Figure 9. Demonstration Dish Room Layout

Figure 9 shows the new layout of the dish room with the new components including the Hobart dish machine, ventilation hood and conveyor for feed racks into and out of the machine.

5.4 OPERATIONAL TESTING

After the baseline testing was completed and the demonstration equipment installed, initial commissioning and adjustment of the equipment was completed to confirm that each component was operating as expected.

The dish machine and booster heater were operated using the procedures in the operational manual for each unit. The functionality of how dishware was cleaned did not change from the baseline methods used with the previous dish machine. How the racks were loaded and removed from the new machine was slightly different, thus the staff had to be trained on how to do this with the new machine. The baseline machine only required a single staff member to operate, but the demonstration machine used two staff members during the initial training of the using the machine. Once trained on how to properly use the new machine, only one staff member was required. The demonstration included the testing and evaluation of the individual units (dish machine with heat recovery system and ventilation system) to evaluate the separate performance objectives associated with each unit. Based on the results from each individual unit, an optimal operation matrix was developed to determine the most effective procedures to operate all the units at the same time to meet the performance objectives of the project.

Table 2 shows the timeline for the demonstration tasks including installation and commission of the new equipment and testing of the new systems.

Table 2. Gantt Chart for Demonstration Tasks

ID	Task Name	Start	Finish	2016	2017				2018	
				Q4	Q1	Q2	Q3	Q4	Q1	Q2
1	Task 3: Installation and Commissioning and Equipment	1/2/2017	8/31/2017							
2	Task 4: Demonstration and Data Analysis	9/14/2017	4/27/2018							

5.5 SAMPLING PROTOCOL

The data was acquired using standard gas meters, electrical meters, thermocouples and hygrometers and controlled and recorded by a data acquisition system. A listing of the data acquisition equipment is given in **Table 3** and general location for sensors for the baseline testing in the dishroom given in **Figure 10** and for the demonstration in **Figure 11**. The figures do not show the energy monitoring equipment that was in the boiler room in the facility for measurement of the energy required by the existing boiler system to produce the hot water for the baseline dish machine, but the equipment is listed in the table. A water meter was installed on the supply line to the boiler to give total water flow. Because the boiler has a modulating burner with a firing rate range of 500,000 to 1,000,000 BTU/hr, a gas meter in the boiler room

was installed on the gas supply of the boiler (Parker 103 – 25 HP) to measure the total energy usage of the boiler. A mass flow meter was installed to give a total energy use in BTU's to the DFAC. The flow and temperature of the supply hot water to the dish machine was monitored. However, accurately measuring steam flowrate is difficult especially at the flowrates and pressures used for the dish machine. The boiler does supply steam to other systems in the DFAC, but with data collected during the baseline monitoring, the project team was able to determine what percentage of the total energy from the boiler is used by the dish machine. Because the new dish machine for the demonstration was not reliant on steam from the boiler, the energy usage of the baseline dish machine was determined by comparing the total energy rate of the boiler during the baseline and demonstration testing. The comparison was made based on equal numbers of racks washed over similar time periods to give as accurate a value as possible.

Because of the difference in how it operates, the demonstration testing had a slightly different layout and set of data acquisition equipment then the baseline as shown in **Figure 11**.

Table 3. Data Acquisition System Equipment Specifications

Equipment	Location	Manufacturer/Model
Water Flow Meter	Dishroom	Model: M25-750-L-L-S-B-TD-XX-XX Nutating Disc Hot Water Flow Meter and PFT-2 Pulse Transmitter (Quantity 5)
Water Flow Meter	Dishroom	Model: M25 Nutating Disc Cold Water Flow Meter (Quantity 4)
Pipe Fittings	Dishroom	Additional NPT Connectors at 1/2" (Quantity 4)
Data Logger	Dishroom	DataTaker DT-80 Datalogger
Cellular Modem	Dishroom	U.S. Robotics Courier Cellular Modem
Enclosure	Dishroom	Integra Enclosure 14x12x6 Premium Line H141206HLL (assume this model)
Humidity Probe Temperature Probe	Dishroom	Vaisala Humidity and Temperature Probe HMP60 Part # HMP60R00A0A3A0 RS485
Temperature Probe	Dishroom	TT-T-24-SLE-500 SPECIAL LIMITS OF ERROR WIRE, 500 feet, Type T
Watt Meter	Dishroom	Continental Control Systems WattNode Pulse WNB-3Y-208-P
Air Flow Meter	Dishroom	Hot-wire anemometer or Rotating vane anemometer Model TBD
Water Flow Meter	Boiler Room	Model: M25-750-L-L-S-B-TD-XX-XX Nutating Disc Hot Water Flow Meter and PFT-2 Pulse Transmitter
Gas Flow Meter	Boiler Room	Gas Meter with Pulse Transmitter Model TBD based on pipe diameter and supply pressure



Figure 10. Location of Baseline Data Acquisition Sensors

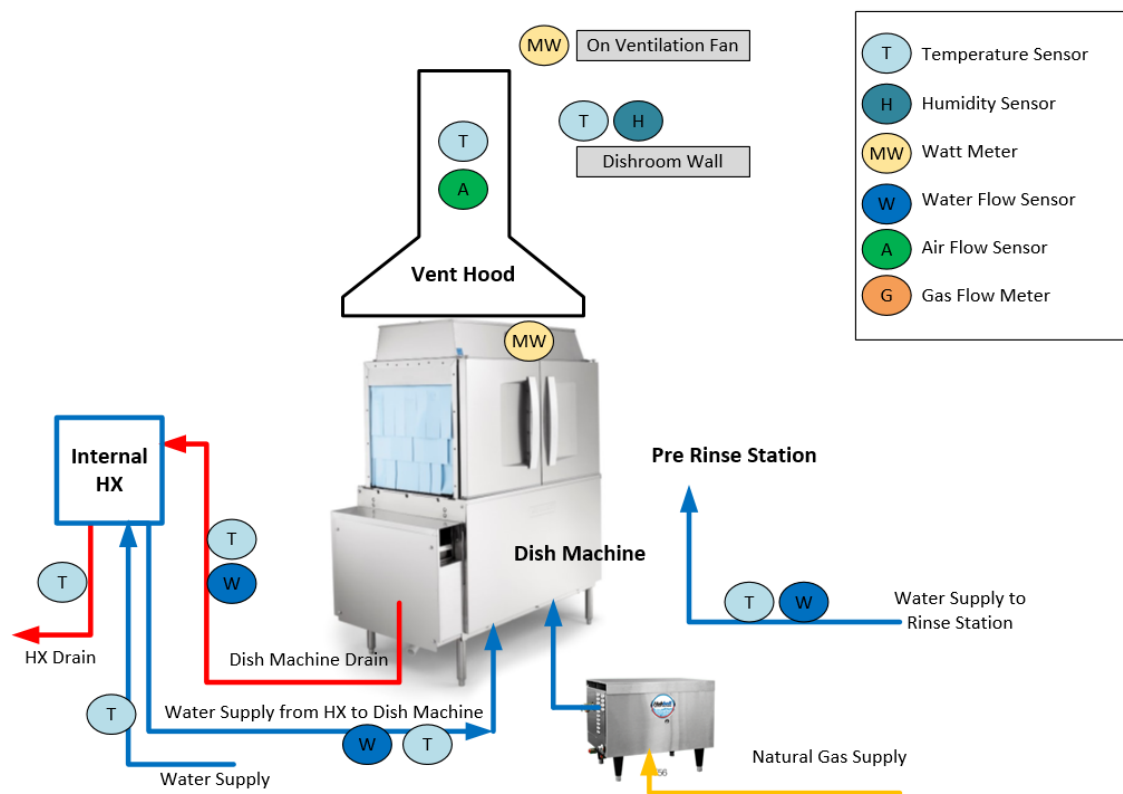


Figure 11. Demonstration Components and Location of Data Acquisition Sensors

The data acquisition equipment was installed so not to interfere with daily operation of the DFAC as shown in **Figure 12**. The equipment is sealed white box underneath the inlet of the dish machine in the lower right of the image.



Figure 12. Data Acquisition Equipment

5.6 SAMPLING RESULTS

The data from the individual sensor were recorded via a DataTaker DT-80 Datalogger and accessed using direct download. The data collection frequency of every 5 seconds was used to ensure the quality of the data by giving enough comparative data to identify errors in the data collection or any misread values. Energy data was checked against the rated energy output of the equipment being tested. This includes the listed BTU/hr firing rates of any gas-fired equipment and wattage of the electric equipment. The installation and calibration check of all the data acquisition equipment will be completed by Frontier Energy. All the data acquisition equipment listed for the baseline and demonstration was calibrated by the manufacturer before delivery. All of the data points in

Figure 10 and **Figure 11** were compiled into a spreadsheet and normalized to values including daily usage, meals served or racks washed. Most of the analysis looked at daily usage, examples include **Figure 13** that charts the total number of meals served each day and **Figure 14** for that chart water usage to pre-rinse racks before entering the dish machine during a portion of the baseline testing. **Figure 15** plots natural gas usage in the boiler room for generating steam to heat the water for the dish machine during a portion of the baseline testing.

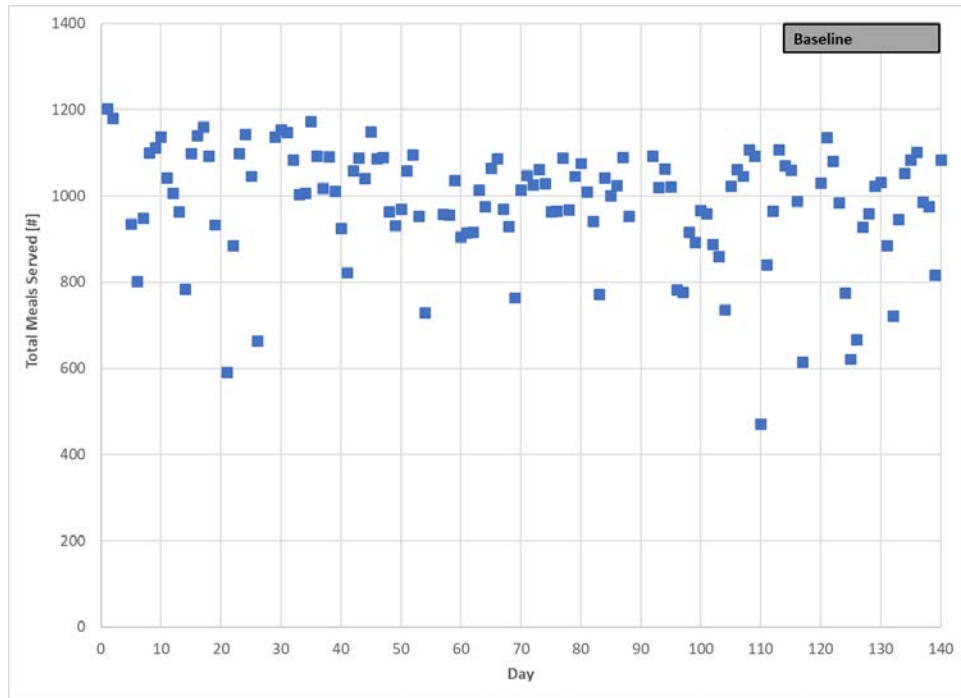


Figure 13. Daily Total Meals During Baseline

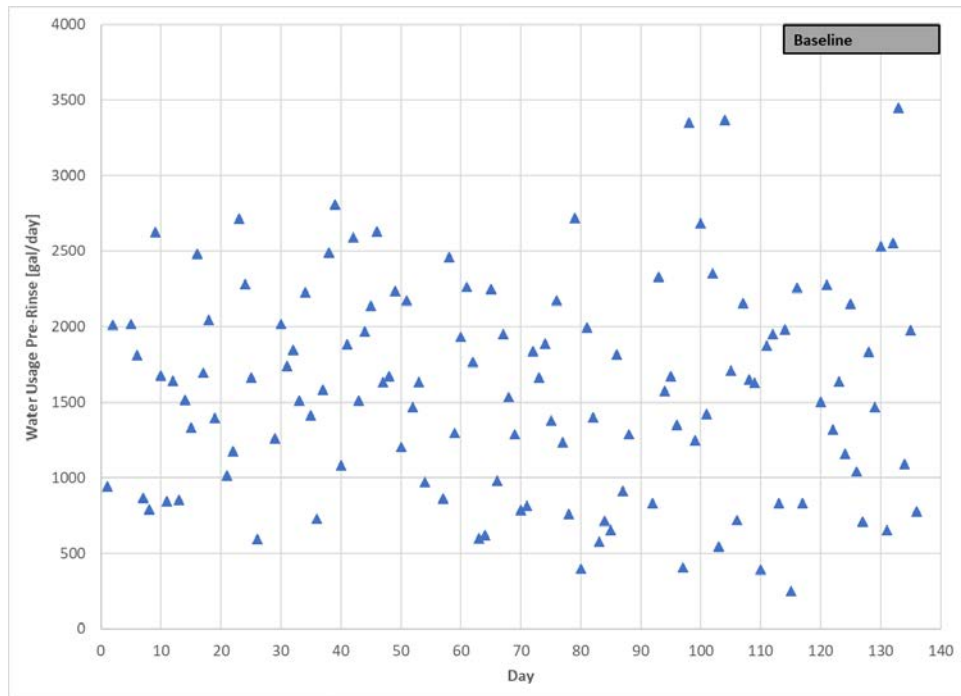


Figure 14. Daily Water Usage for Pre-Rinse During Baseline

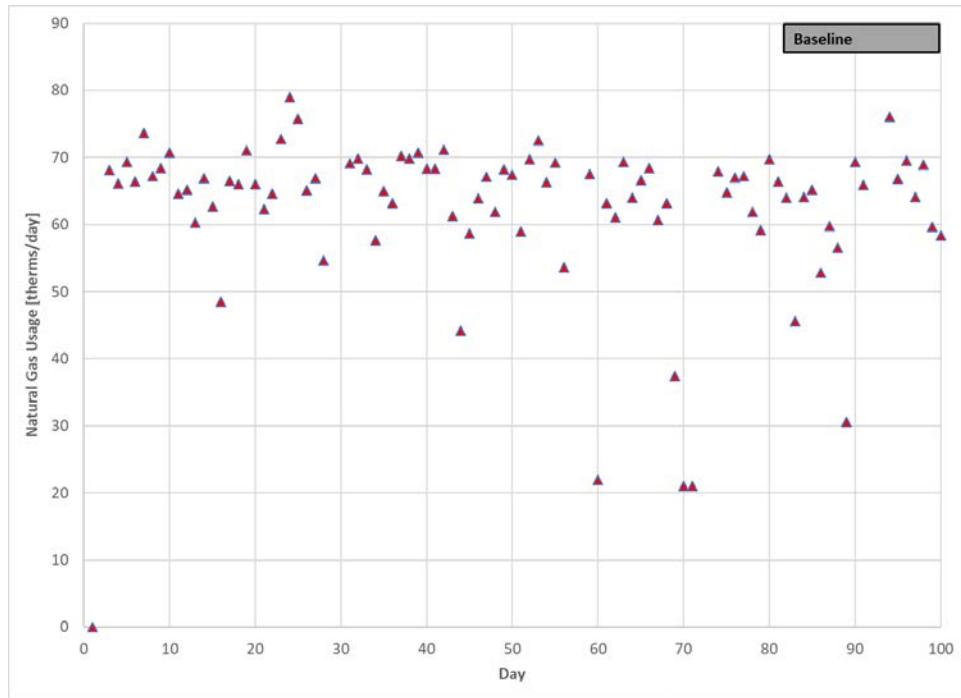


Figure 15. Boiler Room Natural Gas Usage During Baseline

Improved thermal comfort of the working environment was shown both quantitatively and qualitatively. The quantitative data was from recording and comparing the temperature and humidity in the dishroom during baseline and demonstration testing. The qualitative data was based on discussions with the Energy Manager (Jay Tulley) and the DFAC staff about if they noticed any improvement in their comfort level while working in the dishroom during the demonstration compared to the baseline operating conditions. Example data for temperature and humidity is shown in **Figure 16** for a typical day of operation in the dishroom.

More charts and tables from the data is given in the next section of this report to illustrate the results for the performance assessment of performance goals for the project.

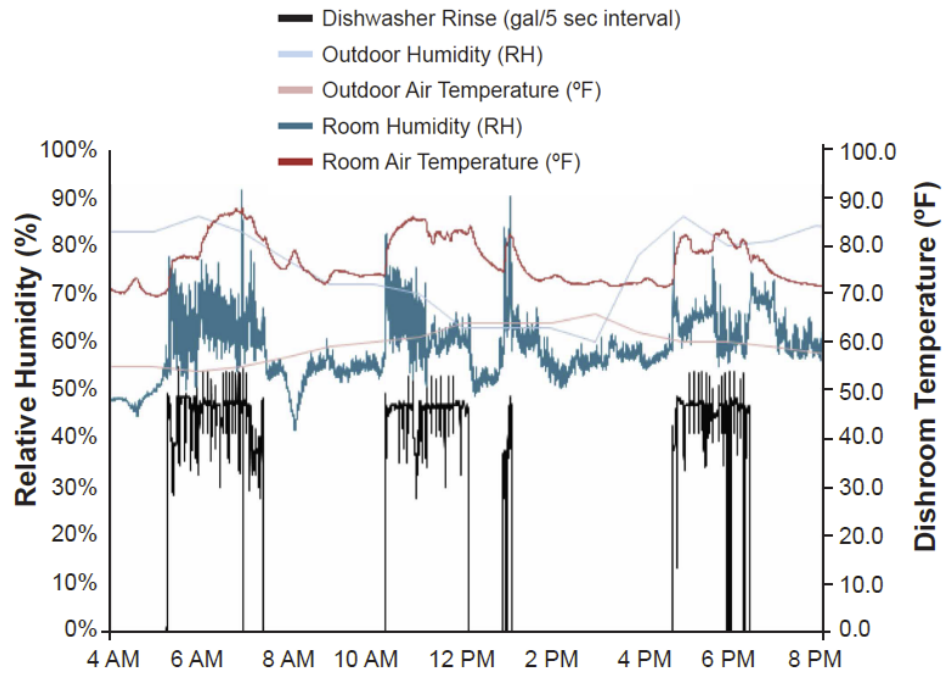


Figure 16. Temperature and Humidity Data in Dishroom

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6.0 PERFORMANCE ASSESSMENT

The key to acquiring accurate data for assessing the quantitative and qualitative performance objectives of the projects was establishing several difference performance characteristics of how the dish room was currently operating during the early stages of the baseline testing. Once the baseline data acquisition equipment was installed, data was measured to determine two key performance characteristics: identify the major sources of water usage and determine the operation load in terms of meals served per day. Identifying the major sources of water usage was important for determining other sources of water usage reduction besides the dish machine. Previous projects suggested that water usage for pre-rinsing could be reduced by replacing existing water nozzles with low flow nozzles. Tracking the meals served per day was important for establishing the daily, weekly, monthly and seasonal usage rates of the dish room so that data from the baseline could be compared with the demonstration. If usage rates varied significantly at different times, then data for both the baseline and demonstration would have to normalized to standard usage rates.

6.1 PERFORMANCE CHARACTERISTIC: OPERATIONAL LOADS IN MEALS PER DAY

An important issue when comparing baseline with demonstration data was assuring the usage rates during these test periods were the same or about the same for the number of meals being served. A consistent number of meals served correlated to a similar number of racks being washed for each meal and daily, weekly and yearly time frames. **Figure 17** plots the total headcount for each day and divided the day up in breakfast, lunch and dinner for 6 months during the baseline testing. There were some variations in the headcount for different days of the week and due to DFAC closures but compared with other similar sized facilities the usage rate is very consistent on a weekly or greater timeframe basis. The average meals served per day was 984.

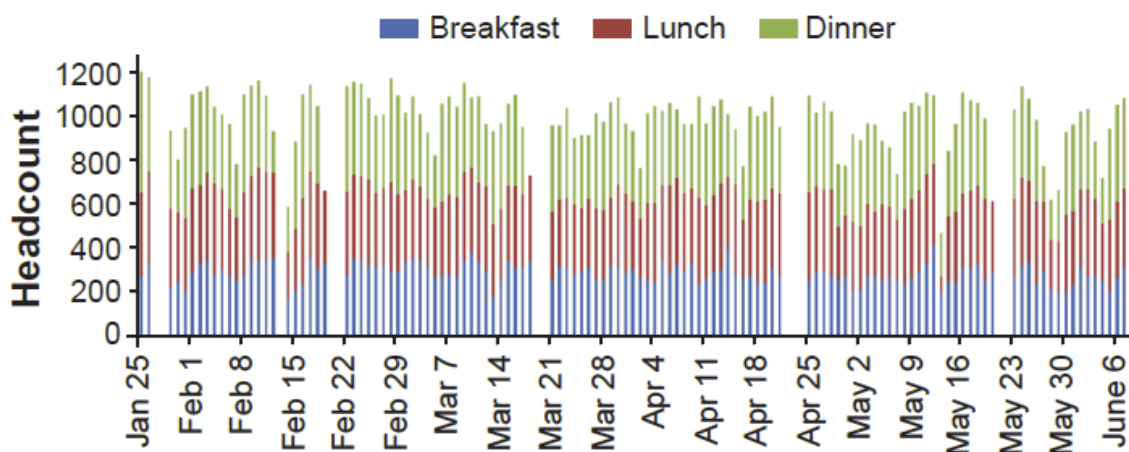


Figure 17. Headcount for Each Meal for 6 Months

The consistent usage rate would be expected to have a consistent water usage rate because the water usage rate per rack is the same for the dishwasher which is typical the largest water usage source in a DFAC. To further refine or normalize the data, the daily water usage rates are divided by the number of meals served that day to remove the variation in number meals served in one day. **Figure 18** shows the average water use per meal in gallons per day for each day of the week. As expected, the water usage for the dish machine or dishwasher was consistent (red data point in the plot). However, the dishroom water use (green data point in the plot) showed significant differences. The dishroom water use is the water used by dish machine plus the other water usage sources in the dishroom such as the utility sink and pre-rinse area.

To further investigate the cause of this variation, data was plotted (**Figure 19**) to show the distribution of gallons of water per meal used. The x-axis for Dishwasher Water Use Per Meal (gal) is for the water to the dish machine and the pre-rinse area. The plot shows a wide variation in water usage. Most days of are within 2.2 to 3.3 gallons per day, but a significant number of days are above 3.5 gallons. Because the dish machine uses a set number of gallons per rack, the data suggest there is a behavioral difference in either how the racks are loaded or water usage at the pre-rinse station. Visual observation showed that the racks were loaded consistently the same way and with the same number of each type of dishware. The next step in understand the water usage in the dish room was to determine the water usage at all locations in the dishroom and determine where the inconsistent usage was coming from.

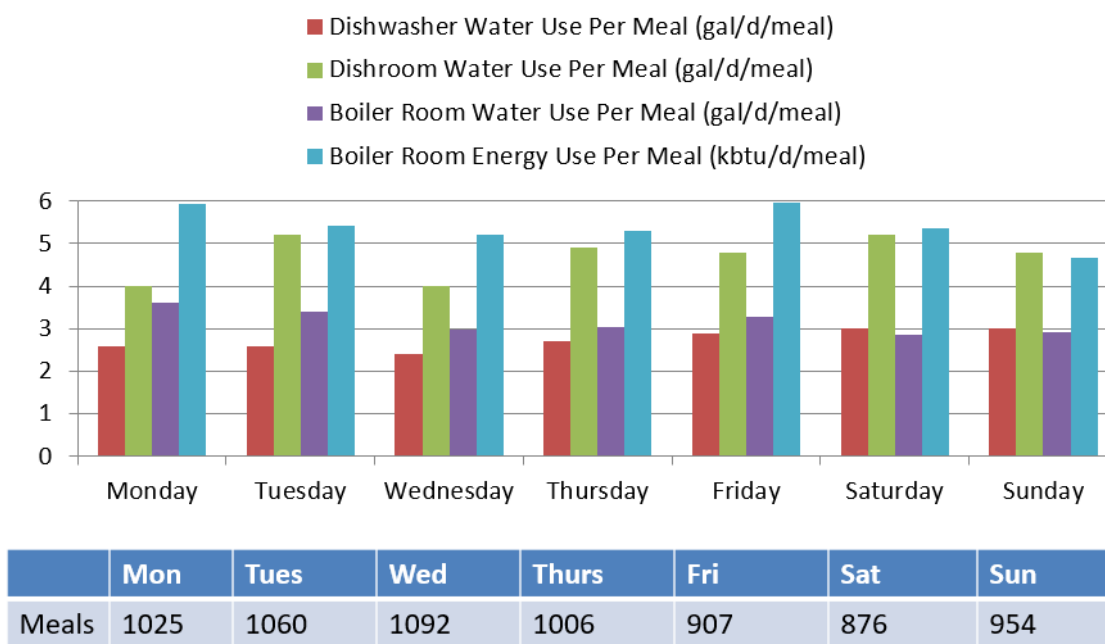


Figure 18. Daily Water Use in Gallons per Day per Meal

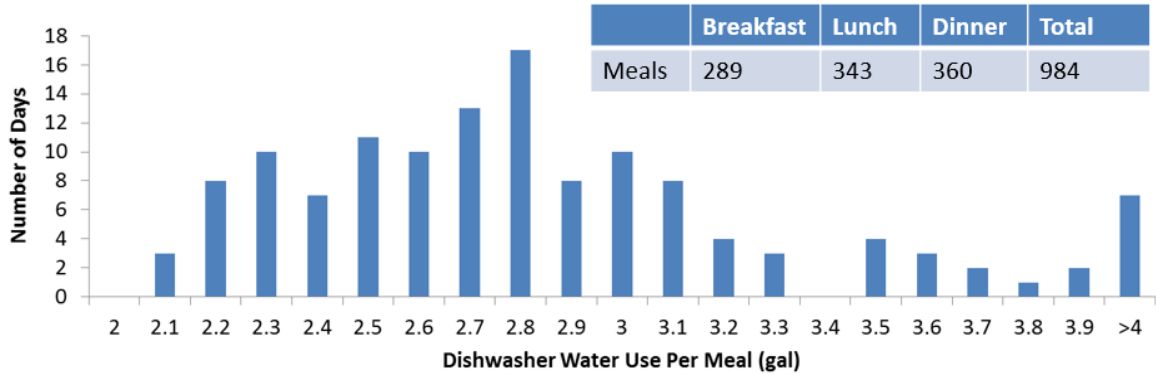


Figure 19. Daily Dishwasher Water Use

6.2 PERFORMANCE CHARACTERISTIC: WATER USAGE PROFILE

Water usage in a dishroom is not limited to the dish machine. **Figure 20** shows the different water usage location in the dishroom that were monitored during the project. The Tank Fill and Hose and Rinse water flows are for the dish machine. The figure shows a significant water usage comes from the pre-rinse. The pre-rinse is done to remove food items and large stains for the dishware before entering the dish machine for cleaning and sanitation. Compared with the total water usage, the pre-rinse usage rate was higher than expected and lead to a deeper investigation of the water usage in the dish room besides the dish machine. As detailed in Section 6.1, the project team identified a potential issue in how water was being used in the pre-rinse area.

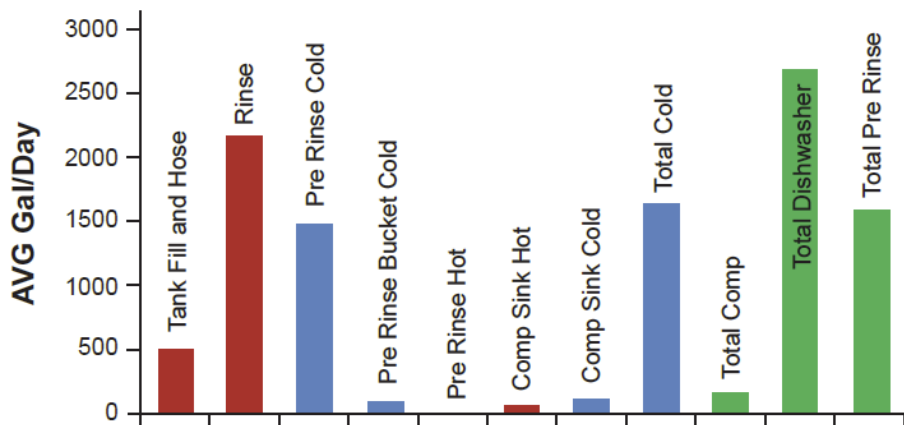


Figure 20. Water Usage in Dish Room

Figure 21 plots data similar to **Figure 19**, but for only the pre-rinse area. The spread for **Figure 21** is similar to **Figure 19**, but more variations for low and high water use. Most day use 1.5 to 1.7 gallons of water per meal to pre-rinse, but a very significant numbers of days use less than 1 gallon and more than 3.4. The gap in the data from 2.8 to 3.5 shows that different methods were being used for the pre-rinse area.

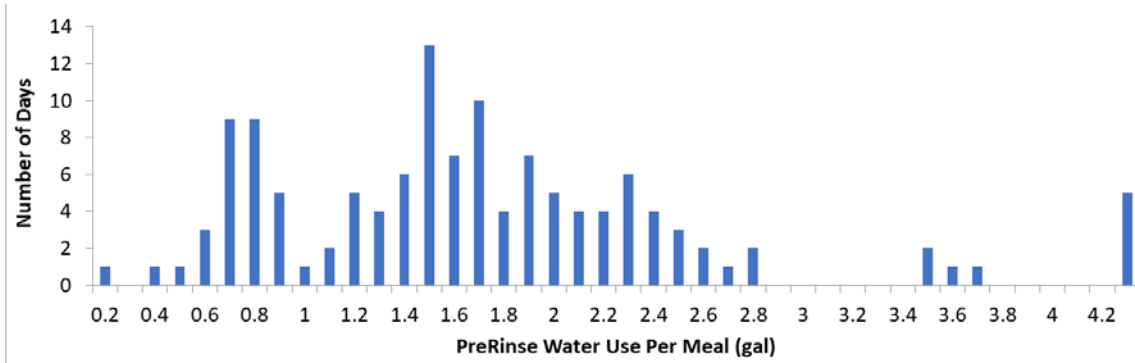


Figure 21. Water Usage for Pre-Rinse Area

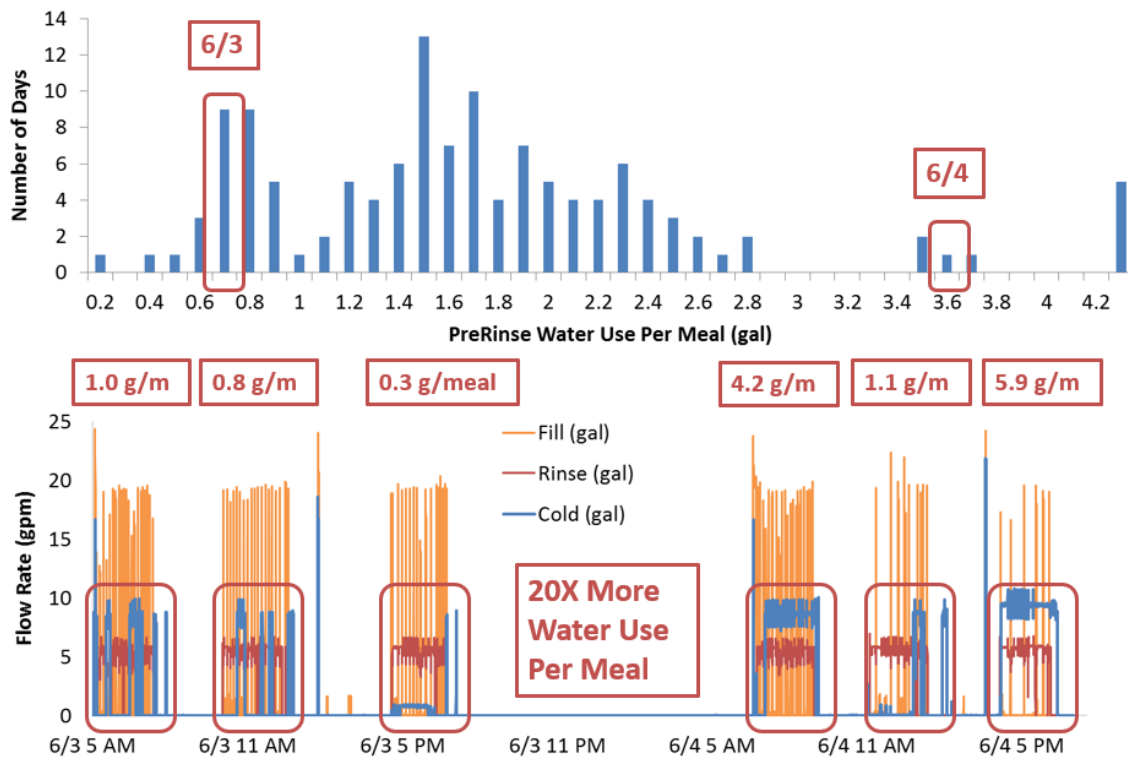


Figure 22. Water Usage for Pre-Rinse Area (Marked Dates)

Figure 22 further shows that the variations in water usage were not a weekly or month trend, but could occur on consecutive days. For the figure, June 4 water usage was 20 times more per meal than for June 3. The main difference in water usage was the blue line for the Cold (gal) which was the hose connection to the pre-rinse area (Note the red line for the Rinse (gal) is the hot rinse water for the dish machine).

After discussions with the site energy manager and observations of dishroom operations over several days of dish washing, the problem was identified. **Figure 23** shows that a garden hose without a nozzle was being used to “wash out” the trough where the scraps collected below the pre-rinse station. On some days, the hose would be left on to continuously wash out the trough. These days when the hose was left on were the greater than 3.5 gallons per meal for the PreRinse Water Use Per Meal in **Figure 21**.



Figure 23. Pre-Rinse Station in Dish Room

On a different day, a single employee was observed to only use the hose to rinse the trough periodically and was using a dry scrapping method to remove the excess food and stains from the dish ware. These days are the less than 1.0 gallons per meal in **Figure 21**.

After identifying this, the project team added a nozzle to hose and recommended using a dry scrapping method to remove larger food items from the dishware. Information for pre-rinse operations was added to a Best Practices Guide for the project.

6.3 QUANTITATIVE PERFORMANCE OBJECTIVE: WATER HEATING ENERGY USAGE

Once the water usage sources within the dishroom were identified, the baseline water usage was monitored for the total volume of water used and the energy required to heat the water for over 6 months. These values were compared with 6 months of water and energy data for the demonstration dish machine. In terms of energy use, the main difference from the baseline to the demonstration unit was that steam generated in the boiler room was the sole source of water heating for the DFAC including the dish machine and a natural gas booster heater was used as the primary heat source for the demonstration machine. The goal for the host site was to replace the steam boiler system with a natural gas system for dish washing and a smaller boiler for hot water in the sinks in the kitchen and bathrooms. During the demonstration, once the new dish machine and booster heater had established the ability to function as required, the larger boiler in the DFCA was decommissioned. The **Table 4** summarizes the energy usage for baseline operations and demonstration operations before and after decommissioning of the boiler system.



Figure 24. Boiler System for Decommissioning in DFAC

Table 4. Results for Energy Use for Dish Washing

Performance Objective	Baseline	Demonstration	Savings	Savings
Total Natural Gas Use	6.7 MMBtu/day	4.7 MMBtu/day 3.3 MMBtu/day*	2.1 MMBtu/day 3.5 MMBtu/day*	31% 51%
Electricity (Conveyor, Pumps, Motor)	28 kWh/day	17 kWh/day	11 kWh/day	41%

* After decommissioning of boiler system

As **Table 4** shows, the use in natural gas in the DFAC was reduced by 31% once the new dish machine with the natural gas booster was put into operation. During the initial months of the demonstration, the natural gas boiler in **Figure 24** was still operation as the hot water supply for the kitchen and bathroom sinks and heating. Eventually the large boiler was replaced with a smaller one because of the reduced capacity requirements. Once the boiler system was decommissioned, the total energy savings for water heating for washing dishes was reduced by 51%. The goal was to achieve a 60% reduction in water heating energy usage and the project team has determined that if the existing boiler system in the DFAC was optimized for the new loads in the DFAC after the demonstration, that further savings could be achieved.

The original performance objective for energy use for water heating did not include energy associated with operating the baseline and demonstration dish machines, including electric motors to operate the conveyor, pump and motors. **Table 4** shows that an additional 41% of electrical energy was saved using the demonstration dish machine. Combining the savings for the two energy types in **Table 4**, gives a total energy savings of 54% for replacing the baseline dish machine with the demonstration unit.

6.3.1 Waste Water Heat Recovery

As detailed in section 5.3, the dish machine chosen for the demonstration has a built-in heat exchanger that uses the waste water to preheat the cold water at the inlet of the booster heater. External heat exchangers like the ones shown in **Figure 25** have been used over that past few years for applications including dish machines, showers, laundries and other waste hot water applications. Specific information about the two designs are given in section 2.1. The disadvantages of these types are clogging from grease or other matter in the waste stream and requiring addition floor space. For these reasons, the project used the Hobart dish machine with on-board heat recovery. This is first design of a commercial dish machine to include this technology. Data from the demonstration showed that the heat exchanger averaged a 42.4 °F increase in water temperature (63.2 °F to 105.6 °F). Based on the usage rates in gallons per day, the heat exchanger saved on average 2.2 therms (or 0.22 MMBtu) per day of natural gas energy. This equates to about 800 therms (or 80 MMBtu) per year or 10.4% percent of the total savings of energy for heating of water to the dish machine.



Figure 25. External Waste Water Heat Recovery Methods

6.4 QUANTITATIVE PERFORMANCE OBJECTIVE: VENTILATION SYSTEM ENERGY USAGE

Past projects by Frontier Energy have shown that typically the ventilation systems in dishrooms are oversized and remove excessive room air from the dishroom and pulls conditioned air from other parts of the facility. The objective for this project was to resize the fan for the ventilation system to properly vent the dishroom to maintain a comfortable work environment and minimize the loss of conditioned air. However, as identified early in the baseline testing, the existing ventilation system was undersized and not properly venting heat and humidity. **Figure 26** shows the ventilation for both the baseline and demonstration dish machines. The baseline carousel machine used a snorkel hood on the exit of the dish machine. This style of hood is effective on removing heat and moisture at the exit of the machine but does not capture heat and moisture build up within the dishroom. This would not be a problem if all the heat and moisture were being generated at only the exit of the machine. However, significant heat is added to the work space by the heated steam lines to the dish machine, leaks in the steam line and directly from the outer shell of the dish machine that heats up during operation. Also, moisture is added to the

work space from the cleaned dishware once it exits the machine, the steam leaks and other processes in the dish room such as cleaning the floor or pre-rinsing. The demonstration conveyor machine is designed to work with a standard hood that is open over the entire machine including the inlet, outlet and pre-rinse area. This style of hood is much more effective on removing heat and moisture from the dish room to maintain a comfortable working environment. However; this style requires a higher ventilation rate with the same or more fan power than the baseline. Because of this change in hood design, there were no savings on the project by properly sizing the ventilation system.



Figure 26. Baseline and Demonstration Ventilation System

6.5 QUANTITATIVE PERFORMANCE OBJECTIVE: SPACE CONDITIONING ENERGY USAGE

As detailed in section 6.4, because of the change in the hood system design as shown in **Figure 26**, there was not a reduction in ventilation rate from the baseline. Because of this, the volume of conditioned air from other parts of the facility being ventilated did not change from the baseline to the demonstration. However, as detailed in section 6.9, significant improvement in terms of comfort level were observed with the demonstration hood system. Data from the baseline also showed that because of the moderate climate at the test site, the facility used much less energy to heat and cool air than locations with more a variation in temperature and humidity.

6.6 QUANTITATIVE PERFORMANCE OBJECTIVE: WATER USAGE

As detailed in sections 6.1 and 6.2, there were many sources of water usage in the dishroom besides just the dish machine. Before the start of the project, it was expected almost all the savings would be from the dish machine with a performance objective of saving 75%.

However, as detailed in section 6.2, additional water savings was achieved by making changes on how dishes were pre-rinsed. These changes included using a low flow water nozzle, dry scrapping and minimizing rinsing of the food scraps trough. **Table 5** list the water savings for only the dish machine and for the for entire dish room including the pre-rinse station. Replacing the baseline carousel dish machine with the demonstration conveyor dish machine saved approximately 89% of water usage or 5,185 gallons per day. Most of the savings is due to the newer machine using much less water to wash a single rack of dishware. However, additional water savings was realized because the design of the baseline carousel machine would allow a cleaned rack to go back through the machine again if not removed once it exited the machine. The demonstration conveyor machine is a once through machine preventing racks from being rewashed. An additional 1,190 gallons per day were saved due to the changes in the operation of the pre-rinse area discussed in section 6.2. The total savings of 6,375 gallons per day equates to approximately 2.33 million gallons of water saved per year in the DFAC.

Table 5. Results for Water Use for Dish Washing

Performance Objective	Baseline	Demonstration	Savings	Savings
Total Water Usage of Dish Machine	5,805 gal/day	620 gal/day	5,185 gal/day	89%
Total Water Usage of Dishroom	7,587 gal/day	1,212 gal/day	6,375 gal/day	84%

6.7 QUANTITATIVE PERFORMANCE OBJECTIVE: SYSTEM SIMPLE PAYBACK

System simple payback is based on the energy water savings vs. the cost of the purchase and installation of the new dish machine. Using the energy and water savings from **Table 4** and **Table 5** and the energy and water blended rate costs provided by the energy manager at the host site, **Table 6** gives the simple payback for energy and water savings. The natural gas savings includes approximately 800 therms of energy saved by the heat exchanger.

Table 6. System Simple Payback

Energy Savings Measure	Savings	Rates	Daily Cost Savings	Yearly Cost Savings
Natural Gas	35 therms/day	\$1.06/therm	\$37.10	\$13,542
Electricity	11 kWh/day	\$0.176/kWh*	\$1.94	\$707
Water	6,375 gal/day	\$0.02/gal	\$127.50	\$46,538

*includes KW demand charges, taxes & fees

Based on the equipment and installation costs from the demonstration of \$136,405 and total yearly cost savings of 60,786, the system simple payback is 2.24 years or about 27 months.

Section 7.0 gives a more detailed cost assessment of replacing the baseline dish machine with the demonstration machine.

6.8 QUANTITATIVE PERFORMANCE OBJECTIVE: DISH MACHINE RELIABILITY

The key parameters for reliability is hours of operation and the rinse temperature. The demonstration has operated for over one year at the time of this report with the only issues being with adjustments to the conveyor system and ventilation hood. The dish machine itself was cleaned dishes and utensils as required by the Tri-Service Food Code TB MED 530 in terms of appearance. The Tri-Service Food Code also sets a requirement for the rinse water temperature to be at least 160 °F to ensure dishware is properly sanitized. The rinse water temperature was measured be at least 160 °F for over 227 days during the demonstration and at no time was it recorded to be less than 160 °F. For some days during the demonstration, the rinse water temperature was not recorded due to measurement equipment issues.

6.9 QUALITATIVE PERFORMANCE OBJECTIVE: USER SATISFACTION IN TERMS OF THERMAL COMFORT OF WORKING ENVIRONMENT

The dishroom in a DFAC or any other foodservice facility is generally the most difficult and uncomfortable area to work in because of the heat and humidity generated by the dish machine. A properly size ventilation system removes heat and moisture from the dishroom to maintain a relatively comfortable work environment. The qualitative assessment for comfort in this project is based on the feedback of the site energy manager and the staff on if the new dishroom with the demonstration machine was more comfortable to work in than the baseline dishroom. Because of the issues with the staff associated with operating the new dish machine, detailed in the Best Practices Guide, there exists a general dislike of using the new machine that prevented getting an unbiased opinion if the new machine improved the comfort level. However; the energy site manager expressed that the work environment was significantly improved with less visible water on the floor. This result is show when assessing the dishroom temperature and humidity during the baseline and demonstration testing. An example of the improvement when comparing 10 days of operation during the baseline and demonstration testing. Figure 27 charts the temperature increases in the dish room from when the dish machine is in operation (ON) and when the dish machine is not operating (OFF) and Figure 28 charts relative humidity for the same operational conditions. The figures show a consistent 10 degrees increase in temperature and 7% increase in relative humidity due to heat and humidity from the dish machine during operation. The result shows that the ventilation system on the baseline unit was most likely not properly venting the space.

Figure 29 and Figure 30 plots the same data for similar operational load days for the demonstration dish machine. The figures show that when the demonstration machine is in operation that the temperature and humidity in room did not increase as much and as consistently as with the baseline unit.

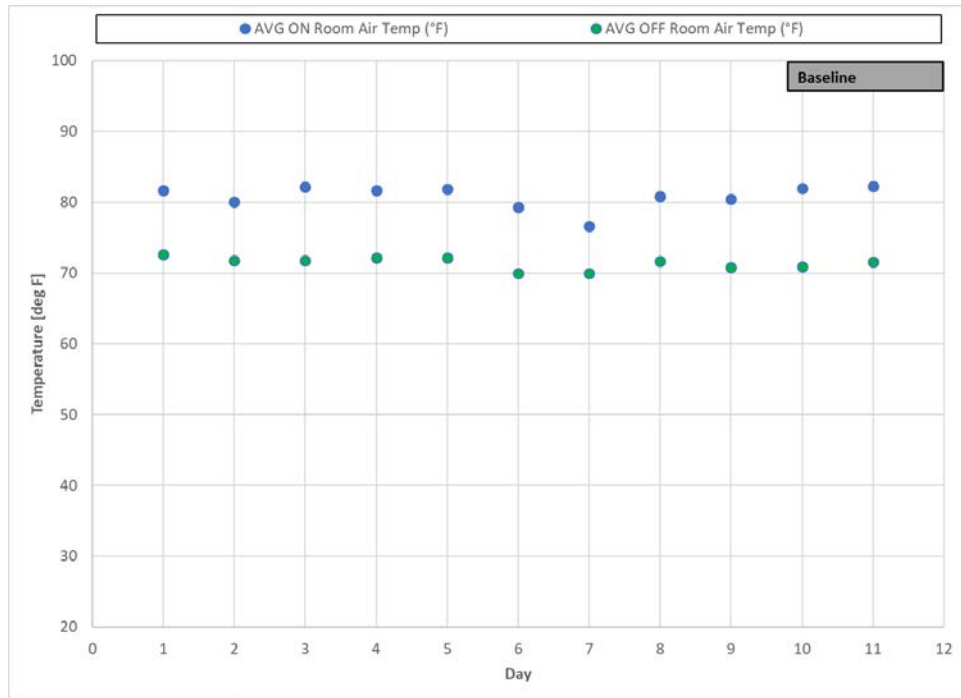


Figure 27. Baseline Dishroom Temperature

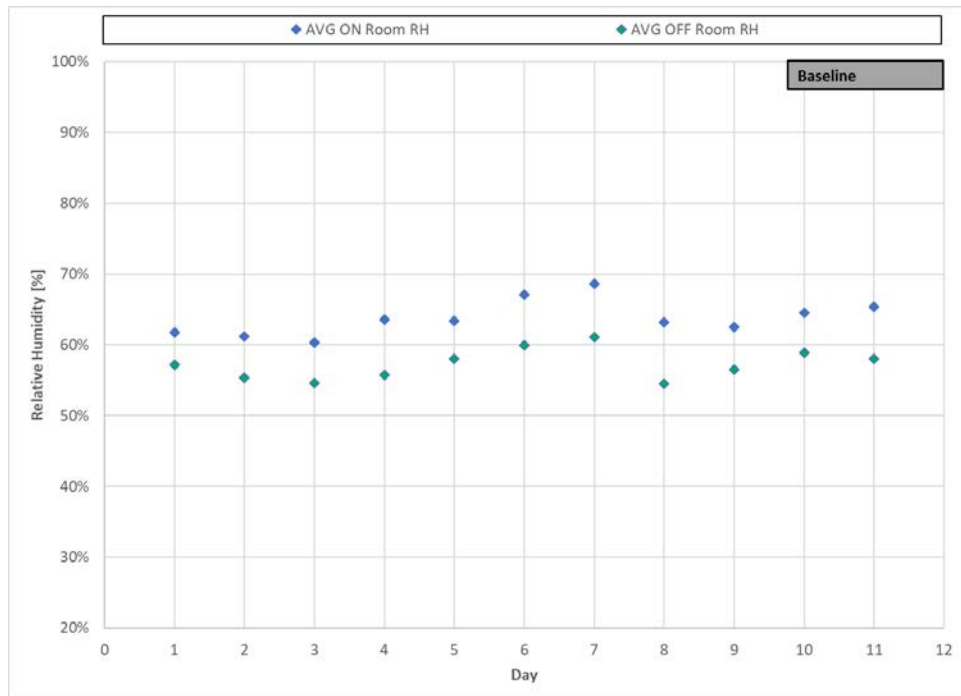


Figure 28. Baseline Dishroom Relative Humidity

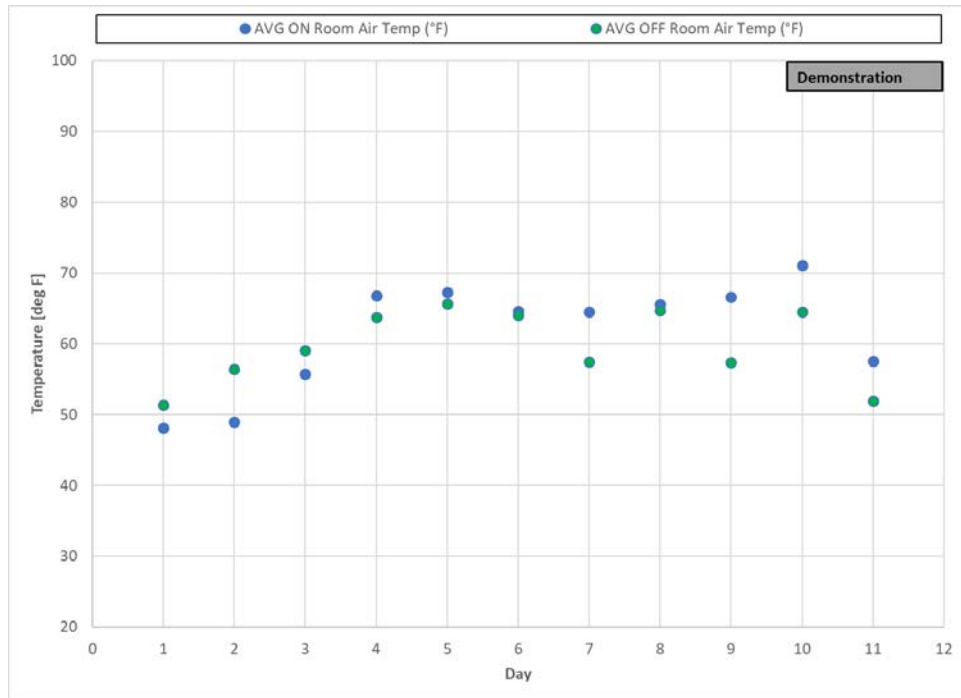


Figure 29. Demonstration Dishroom Temperature

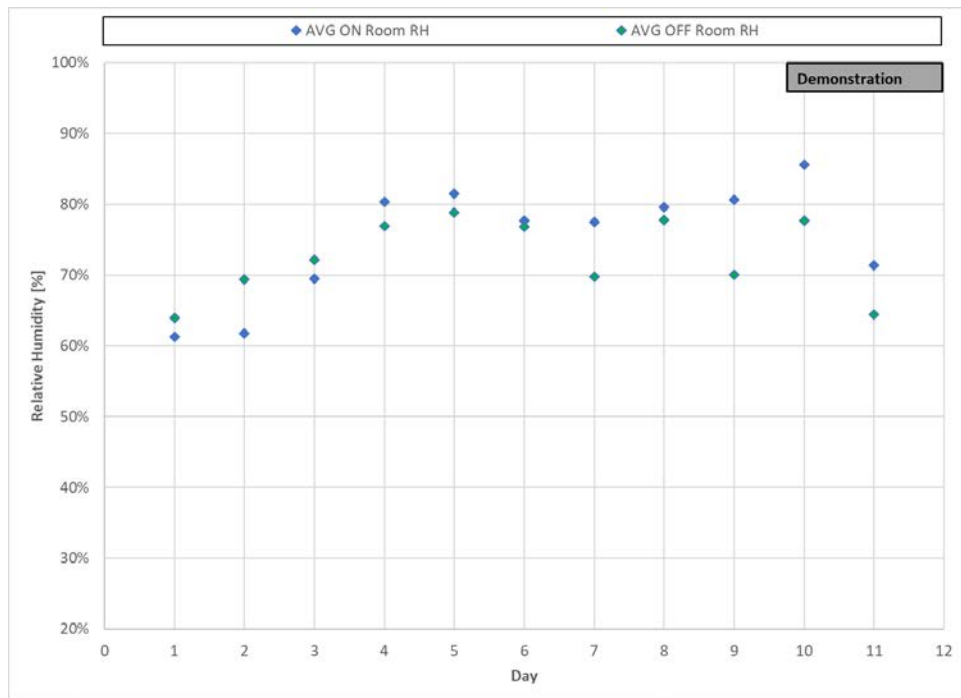


Figure 30. Demonstration Dishroom Relative Humidity

6.10 QUALITATIVE PERFORMANCE OBJECTIVE: USER SATISFACTION IN TERMS OF CLEANING PERFORMANCE

According to Tri-Service Food Code TB MED 530, all dishware must be visibly clean and sanitized. The rinse water temperature was measured to be at least 160 °F during the demonstration showing that the dishware was properly sanitized. Visual inspection of the dishware also meets with the requirements of the Tri-Service Food Code. **Figure 31** shows a rack of cleaned dishware from the demonstration dish machine.



Figure 31. Cleaned Dishware

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7.0 COST ASSESSMENT

The cost assessment and formation of a cost model for the replacement of an existing dish machine with an energy and water savings unit depends on the type of machine being replaced. As for this project, the existing machine was a carousel type that required a new dish room layout, conveyor feed system, energy supply and hood to be replaced with a conveyor dish machine. This type of replacement is more expensive compared to replacing an older machine with the same type of machine i.e. conveyor, door or flight. The cost analysis will include both types of replacement based on the results of the demonstration.

7.1 COST MODEL

The cost elements for implementing the change for an older carousel style dish machine to an energy efficient conveyor are listed in **Table 7**. The capital costs include the cost of the dish machine from Hobart, the gas booster from Hubbell, installation of natural gas supply line and changes to the pre-rinse station, dish table and conveyor system to accommodate the new machine. The last three would not be required if the baseline and demonstration dish machine were the same type. Installation costs include installation of the dish machine and the cost of the kitchen consultant. A kitchen consultant was needed for this project because of the extensive changes needed for the new layout of dishroom due to changing to a conveyor machine. Consumables include the cost of compostable dishware that was used to serve meals on because the DFAC had to stay in operation during the installation. The estimated cost of \$8,000 per year for washing detergent is based on the demonstration and other dish machine projects. Because the baseline and demonstration machines are high temperature units using hot water to sanitize dishes, chemical for sanitization are not needed. The table includes an estimated cost for training of the staff for how the operations of the dish room will need to change for a new conveyor unit. As discussed in the Best Practices Guide for this project, the project team strongly suggests doing this during the baseline testing or before the installation of a new dish machine. Another cost is recommended annual maintenance including having qualified technicians perform an inspection and do tasks such as clean the filters, remove scale from heating elements, replace seals if needed.

Table 7. Cost Model for an Energy Efficiency Dish Machine (Carousel to Conveyor)

Cost Element	Data Tracked During the Demonstration	Estimated Costs
Hardware capital costs	Dish Machine, Booster Heater, Hood, Conveyor, Pre-Rinse Station, Dish Table, Gas Line	\$77,302
Installation costs	Kitchen Consultant, Dish Machine	\$32,603
Consumables	Compostable Dishware: used during installation to keep DFAC operational	\$16,000
	Dish Washing Detergent: \$/year	\$8,000
Facility operational costs	Reduction in energy required vs. baseline data	\$14,248
	Reduction in water required vs. baseline data	\$46,537
Maintenance	Frequency of required maintenance	yearly
	Labor and material per maintenance action	\$500
Hardware lifetime	Estimate based on components degradation during demonstration	20 years
Operator training	Estimate of training costs	\$2,500

The cost model would change significantly if the baseline dish machine is the same type as the replacement. Cost elements like changes to the dish room layout and hood, operator training, installation and kitchen consultant would not be needed or greatly reduced. Also, if the facility can be shut down during the installation, replacement dishware would not be needed. **Table 8** gives estimated costs if the baseline machine had been a conveyor type machine instead of a conveyor. The table removes the 15% discount on the dish machine that was given for this project. The total cost difference between replacing a conveyor with a conveyor and a carousel with a conveyor is estimated to be \$54,572 or 27% less. An equal amount of savings (9% each) is from the difference in hardware and installation costs. Consumables (dishware used during installation) saves about 4% and training saves about 1%. Thus, most of the cost is associated with installation costs associated from changing to a new type of machine, including hiring a consultant to redo the dish room layout.

Table 8. Cost Model for an Energy Efficiency Dish Machine (Conveyor to Conveyor)

Cost Element	Data Tracked During the Demonstration	Estimated Costs
Hardware capital costs	Dish Machine, Booster Heater, Hood Modifications	\$58,833
Installation costs	Kitchen Consultant, Dish Machine	\$15,000
Consumables	Dish Washing Detergent: \$/year	\$8,000
Facility operational costs	Reduction in energy required vs. baseline data	\$14,248
	Reduction in water required vs. baseline data	\$46,537
Maintenance	Frequency of required maintenance	yearly
	Labor and material per maintenance action	\$500
Hardware lifetime	Estimate based on components degradation during demonstration	20 years

7.2 COST DRIVERS

The biggest cost driver for any future installation is how much will the existing dish room have to be modified to work with a new dish machine. As **Table 7** and **Table 8** shows, the cost difference between a dish room requiring extensive changes and one that doesn't is estimated to be \$55,000. Also, addition cost will be incurred if the dish room must remain operational during the installation. A typical installation where the same type of machine is replaced should not take as long as for this project where a carousel machine was replaced with a conveyor machine. Significant time and planning is needed to redo the dish room layout to accommodate the new type of machine. Also, \$16,000 in compostable dishware would not be needed because the period of time the dish room would be unviable would be significantly less, potentially for only 2 to 5 days.

7.3 COST ANALYSIS AND COMPARISON

The cost of implementing new dish machine technology is dependent on how much modification is required to the layout of the dishroom. For this demonstration, extensive changes were needed including redesigning the pre-rinse station, dish table, conveyor system and ventilation hood. This is reflected in the hardware and installation costs in **Table 7**. As shown in **Table 8**, if the baseline unit was a conveyor unit like the replacement, the hardware and installation costs would be much less. The lifetime costs for both replacement types is listed in **Table 9**. Equipment & Installation Costs includes costs of buying the equipment, purchasing compostable dishware to use during installation, installing a new hood, modifying the pre-rinse station, modifying the dish table and conveyor, adding a gas line and hiring a kitchen consultant. Yearly Costs include cost of cleaning chemicals, maintenance, energy (gas and electric) and water. The natural gas savings includes approximately 800 therms of energy saved by the heat exchanger. The table also includes estimations for lifetime costs if the baseline carousel dish machine was replaced with a new machine of similar design. The estimates for equipment and installation costs are based from information from the kitchen consultant for the project. The only costs in the table that would vary based on location is the energy costs in the Yearly Costs. Compared to the energy costs the region of California for the demonstration site, rates are generally 10-15% less expensive in the northeast US, 20-25% less expensive in the southeast and Midwest and 25-30% less expensive in Texas. The new machine resulted in about \$14,000 per year for energy savings (therms of natural gas and kWh of electricity) and \$46,500 per year in water savings. Labor costs should did not change from the baseline to the demonstration machine except for the cost of training the staff on using the new type of machine in a new dish room layout.

Table 9. Replacement Dish Machine Lifetime Costs

Installation Type	Equipment & Installation Costs	Yearly Costs	Expected Equipment Operational Life	Lifetime Cost
New Machine w/ Extensive Layout Changes	\$128,405	\$31,208	20 years	\$3,192,260
New Machine w/ Same Layout	\$73,833	\$31,208	20 years	\$2,100,820
Baseline Machine	\$150,000	\$91,993	20 years	\$4,839,860

The new machine resulted in about \$14,000 per year for energy savings (therms of natural gas and kWh of electricity) and \$46,500 per year in water savings. Labor costs should did not change from the baseline to the demonstration machine except for the cost of training the staff on using the new type of machine in a new dish room layout. Values from **Table 9** are used to form **Table 10** to determine the relevant cash flows for a life-cycle cost analysis (LCCA) using methods defined in NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program (FEMP). The residual value is assumed to be the scrap value of the metal from the dish machines at the end of its useful life.

Table 10. LCCA Model Information

Relevant Cash Flows	Baseline Machine	New Machine w/ Extensive Layout Changes	New Machine w/ Same Layout
Initial investment costs, assumed to occur in a lump sum	\$150,000	\$128,405	\$73,833
Residual value at the end of the 20-year study period	\$1,500	\$1,500	\$1,500
Annual energy costs (natural gas and electric)	\$28,108	\$13,860	\$13,860
Annual water costs	\$55,385	\$8,848	\$8,848
Annual O&M costs (chemicals and maintenance)	\$8,500	\$8,500	\$8,500

The LCCA for each type of installation is calculated and shown in the following tables below.

Table 11. LCCA Model Calculation for Baseline Machine

Cost Item	BaseDate Cost	Year of Occurrence	Discount Factor	Present Value
Initial investment costs, assumed to occur in a lump sum	\$150,000	Base Date	Already in present value	\$150,000
Residual value at the end of the 20-year study period	(\$1,500)	20	$SPV_{20} 0.554$	(\$831)
Annual energy costs (natural gas)	\$26,309	Annual	$FEMP UPV_{20} 20.24$	\$532,494
Annual energy costs (electric)	\$1,788	Annual	$FEMP UPV_{20} 15.69$	\$28,054
Annual water costs	\$55,385	Annual		\$1,001,361
Annual O&M costs (chemicals and maintenance)	\$8,500	Annual	$UPV_{20} 14.88$	\$126,480
			Total LCC	\$1,837,558

Table 12. LCCA Model Calculation for Demonstration Machine with Extensive Layout Changes

Cost Item	BaseDate Cost	Year of Occurrence	Discount Factor	Present Value
Initial investment costs, assumed to occur in a lump sum	\$128,405	Base Date	Already in present value	\$128,405
Residual value at the end of the 20-year study period	(\$1,500)	20	SPV ₂₀ 0.554	(\$831)
Annual energy costs (natural gas)	\$12,768	Annual	FEMP UPV ₂₀ 20.24	\$258,424
Annual energy costs (electric)	\$1,092	Annual	FEMP UPV ₂₀ 15.69	\$17,133
Annual water costs	\$8,848	Annual	UPV ₂₀ 18.08	\$159,972
Annual O&M costs (chemicals and maintenance)	\$8,500	Annual	UPV ₂₀ 14.88	\$126,480
			Total LCC	\$689,583

Table 13. LCCA Model Calculation for Demonstration Machine with Same Layout

Cost Item	BaseDate Cost	Year of Occurrence	Discount Factor	Present Value
Initial investment costs, assumed to occur in a lump sum	\$73,833	Base Date	Already in present value	\$73,833
Residual value at the end of the 20-year study period	(\$1,500)	20	SPV ₂₀ 0.554	(\$831)
Annual energy costs (natural gas)	\$12,768	Annual	FEMP UPV ₂₀ 20.24	\$258,424
Annual energy costs (electric)	\$1,092	Annual	FEMP UPV ₂₀ 15.69	\$17,133
Annual water costs	\$8,848	Annual	UPV ₂₀ 18.08	\$159,972
Annual O&M costs (chemicals and maintenance)	\$8,500	Annual	UPV ₂₀ 14.88	\$126,480
			Total LCC	\$635,011

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8.0 IMPLEMENTATION ISSUES

The Presidio at Monterey was not required to acquire traditional building permits, but the proposed design of the dishroom for the demonstration with the new equipment was reviewed and approved internally to follow the required codes. All construction and installation activities were following local codes mandated by the City of Monterey Office of Plans and Public Works, thus any future sites should consult with local codes officials during the planning stages.

For installation in other DFAC locations, other various military codes that may apply include: Whole Building Design Guide (Section 11 48 00, Cleaning and Disposal Equipment for proper installation and operation) and the Tri-Service Food Code TM MED 350 (Construction and Installation section of Chapters 4, 5 and 6).

Because the basic methodology of operating the dish machine was not going to change from the baseline to the new machine, a kitchen designer was not used during the early stages of the project. The plan was to place a new machine into the existing footprint of the old machine and use the same conveyor system to move trays from the drop off location to the pre-rinse station to the dish machine. However, as the baseline testing was coming to an end, it was determined that the existing layout of the dishroom and the location of the hoods would not work with the new machine. Also, the pre-rinse station needed to be relocated. After working with the site energy manager and existing staff, it was determined an experienced kitchen designer was needed to meet the needs of the site, incorporate new plans of the usage of the dishroom and to determine the dish machine and hood location. If a designer had been used in the early stages of the project, several issues and delays could have been avoided. The team eventually hired the original designer of the facility to assist with the new layout. Based on this experience, it is highly recommended before doing any changes to a dishroom to hire an experienced DFAC kitchen designer.

Another learned lesson was to use an experienced and local installer if possible. Several delays to the project occurred because the nearest installer was located over an hour away from the site. There also were issues with the installer on getting to site and determining the correct location of the new equipment in the site. Including a kitchen designer in the early stages would have helped. The Best Practices Guide for this project further details some of the installation issues for this project.

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9.0 REFERENCES

- ASHRAE Standard 55-2004,
<https://www.ashrae.org/File%20Library/docLib/StdInterpretations/IC55-2004-3.pdf>
- ASHRAE Transactions, 2012, Volume 118, Part 1, “Extremely Low-Energy Design for Army Buildings: Dining Facility”, Deru, M., Liesen, R., Langner, R., Herron, D., Zhivov, A., Smith, V.
- DOE, 2003, Buildings Energy Data Book
<http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.13>
- DoD, 2003, Unified Facilities Criteria (UFC) Design: Dining Facilities, UFC 4-722-01. 27 January 2003. https://www.wbdg.org/ndbm/pdfs/archive/ufc4_722_01_draft_0209.pdf
- Energy Independence and Security Act of 2007, Sec. 421 Commercial high performance green buildings, <http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf>
- Energy Policy Act of 2005, Sec 131 Energy Star program, Sec 136 Energy conservation standard for commercial equipment, <https://www.congress.gov/bill/109th-congress/house-bill/6>
- Energy Security MOU with DOE, <http://www.energy.gov/sites/prod/files/edg/media/Enhance-Energy-Security-MOU.pdf>
- Energy Star, Commercial Dishwashers,
https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers
- Executive Order (EO) 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," <https://www.fedcenter.gov/programs/eo13423/>
- Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," <https://www.fedcenter.gov/programs/eo13514/>
- Federal Leadership in High Performance and Sustainable Buildings MOU 2006,
http://archive.epa.gov/greenbuilding/web/pdf/sustainable_mou.pdf
- Johnson, F. (Gas Technology Institute), D. Fisher (Fisher Nickel), L. Brand (Gas Technology Institute), and E. Huestis (PG&E ATS). 2013, “Advanced Foodservice Appliances for California Restaurants Final Report,” California Energy Commission, PIER Building End-Use Energy Efficiency Program. CEC-500-09-044.
- Hobart CLPS86E Specification Sheet,
<https://www.hobartcorp.com/products/commercial-dishwashers/conveyor-type/clen-dishwasher>

PT 56 Specification Sheet,

<http://www.hubbellheaters.com/downloads/catalogs/Hubbell%20PT%20Gas%20Booster%20Series.pdf>

NIST Handbook 135, 1995, Life-Cycle Costing Manual for the Federal Energy Management Program, <http://fire.nist.gov/bfrlpubs/build96/PDF/b96121.pdf>

Design Guide Improving Efficiency of Rack Conveyor Dishwashers Water, Energy and Chemical Savings, 2016, Frontier Energy, https://caenergywise.com/design-guides/Rack_Conveyor_Dishwasher_Design_Guide.pdf

Strategic Sustainability Performance Plan, Sub-Goal 1.1, Sub-Goal 2.1, http://www.denix.osd.mil/sustainability/upload/DoD-SSPP-FY14-FINAL-w_CCAR.pdf

Tri-Service Food Code TM MED 350, <https://archive.org/details/NAVMEDP50101TriServiceFoodCode>

Whole Building Design Guide, Section 11 48 00, Cleaning and Disposal Equipment for proper installation and operation, <https://www.wbdg.org/>

APPENDIX A POINTS OF CONTACT

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ADDITIONAL APPENDICES

During the baseline and demonstration testing of the project, several best practices were identified that could have significant time, energy and water savings if identified during the initial stages of the project. Some of these practices would be applicable to existing installations that are not planning a change in equipment. These

lessons are detailed in a separate document, Best Practice Guide EW 201518. The following is summary of recommended best practices for installing a new or replacement dish machine that could have significant time, energy and water.

- ✓ Evaluating existing water usage practices
- ✓ Using kitchen designers in the early stages
- ✓ Using installer experienced with DFACs and located near the site
- ✓ Inform and educate the staff on using the new equipment
- ✓ Other water savings: trayless service

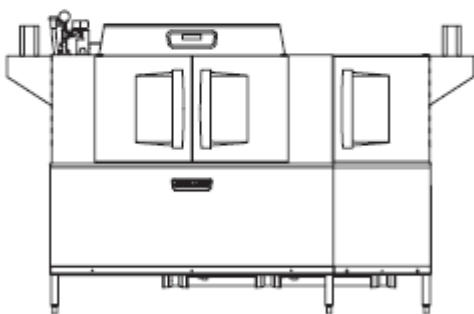


Project _____
AIA # _____ SIS # _____
Item # _____ Quantity _____ C.S.I. Section 114000



CLPS86eN-BAS GAS

High Temperature Rack Conveyor Dishwashing Machine



SPECIFIER STATEMENT

Specified dishwasher will be Hobart conveyor CLPS86eN base model with Opti-Rinse™ and computational fluid designed self-aligning wash manifolds, wash tank, rinse tank, 22" power scrapper tank, (342) racks/hour, insulated hinged doors, .39 gallon/rack, stainless steel enclosure panels, microprocessor controls with low temperature & dirty water indicators, ENERGY STAR®, top mounted computer controls, and NSF approved pot and pan cycle mode. The wash tank utilizes durable precision pressure sensor monitors in lieu of conventional mechanical floats. The 19.5" standard chamber height will accommodate up to (6) standard sheet pans at a time on an open-end sheet pan rack.

NOTE: Contact Hobart sales if remote external gas booster is required.

STANDARD FEATURES

- + 342 racks per hour
- + 22" power scrapper plus separate wash and rinse tanks
- + Opti-Rinse™ system
- + Rapid return conveyor drive mechanism
- + Large double door opening for ease of cleaning
- + Doors are insulated & hinged with door interlock switches
- + 19.5" chamber height opening (accepts sheet pans)
- + Top mounted micro-processor control module
- + Energy saver mode (programmable auto-shut down)
- + Dirty water indicator
- + Manager activated low temperature alert
- + NSF rated configurable pot and pan dwell mode
- + Configurable "intelligent" delime notification
- + Service diagnostics
- + Self-aligning wash manifolds
- + Stainless steel anti-clogging wash arms
- + Removable pump intake screen
- + Stainless steel self-draining pump and impeller
- + Single, sloping scrap screen and deep scrap basket
- + Stainless panels enclose perimeter and bottom
- + Door actuated drain closure
- + Convertible hot water or low temp final rinse
- + Vent fan and booster heater control
- + ENERGY STAR® Certified

OPTIONS & ACCESSORIES (Available at extra cost)

- ☐ Standard, short, and extended stainless steel vent hoods (see page 4 for details)
- ☐ Direct drive unloader – adds 38" length. Reference spec F39520 for more details
- ☐ Side loader – SL23 adds 23" length, SL30 adds 30" length. Reference spec F8066 for more details
- ☐ Blower-dryer – adds 33 1/4" to length. Reference spec F40252 for more details (ships separate from dishmachine, contact Hobart Service for installation)
- ☐ Drain water tempering kit (Drain water tempering kit comes standard on the Drain Water Energy Recovery and Advansys models)
- ☐ Flanged feet kit (requires two kits)
- ☐ Internal stainless steel pressure-less 30 kW booster heater field convertible to 15 kW
- ☐ Higher than standard chamber
- ☐ Table limit switch
- ☐ Correctional institution requirements (contact Hobart for details)
- ☐ PRV & water hammer kit
- ☐ Factory-mounted circuit breakers (contact Hobart for details)

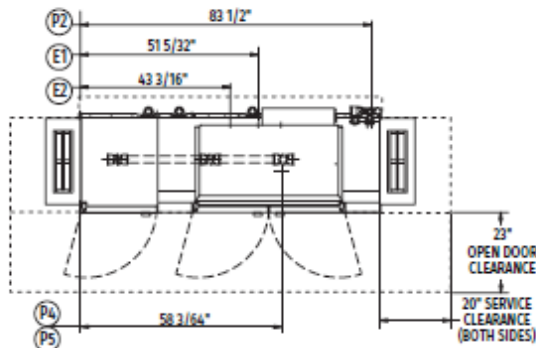
CLen SERIES – CLPS86eN-BAS GAS

Approved by _____ Date _____ Approved by _____ Date _____

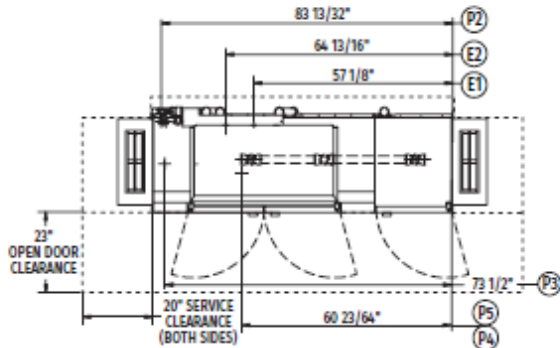


CLPS86eN-BAS GAS

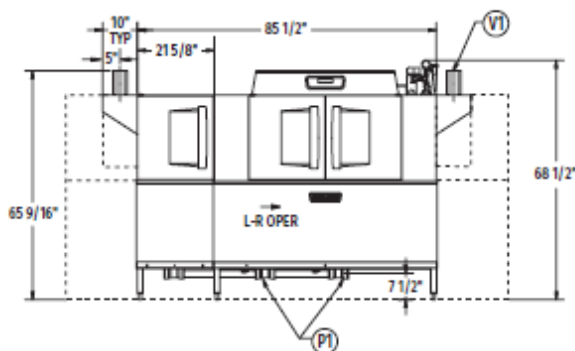
High Temperature Rack Conveyor
Dishwashing Machine



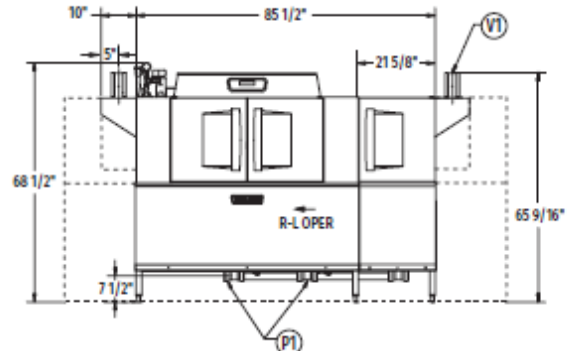
Top View Left to Right



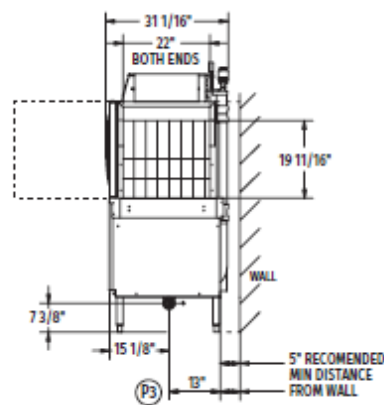
Top View Right to Left



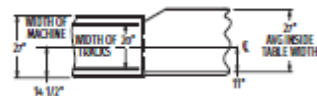
Front View Left to Right



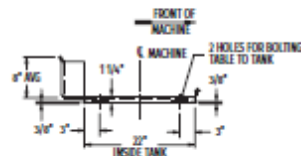
Front View Right to Left



Side View



Suggested Track and Table Layout



View Showing Hole Locations in Turned Down Portion of Table

MODEL:
CLPS86eN-BAS
L-R OPERATION
D-SHALL
REV B

MODEL:
CLPS86eN-BAS
R-L OPERATION
D-SHALL
REV B



CLPS86eN-BAS GAS

High Temperature Rack Conveyor Dishwashing Machine

LEGEND

Electrical Connections	
E1	Motors and controls 1-1/4" or 2" conduit, 63-3/4" AFF.
E2	Booster electrical connection (in lieu of external gas booster) 1-1/4" or 2" conduit, 63-3/4" AFF.
NOTE: Common electrical connection (single point) available, see page 4 for details. Booster information, see page 4.	
Plumbing Connections	
P1	Drain. May be drained to either side of valve, plug opposite side 2" FPT. Recommend a floor drain minimum of 12" from machine for access and maintenance. 7-3/8" AFF.
P2	Hot water. 1/2" FPT connection. Hot water main 1/2", 11-3/16" AFF.
P3	Optional cold water connection for drain water tempering 1/2" FPT, cold water temperature 80°F, maximum 7-3/8" AFF.
Gas Connections (Natural Gas P4 or L.P. P5)	
P4	Gas connection – natural, 1/2" FPT, 10-3/4" AFF; 3.5" minimum, 7" maximum W.C. incoming.
P5	Gas connection – L.P., 1/2" FPT, 10-3/4" AFF; 8" minimum, 11" maximum W.C. incoming.
Vent Connections	
V1	4" x 16" Optional vent hoods w/damper optional extended vent hoods w/damper. Load end vent connection – 200 CFM 0.25" water column; Unload end – 400 CFM 0.25" water column.

WARNING: Plumbing and electrical connections should be made by qualified personnel who will observe all the applicable plumbing, sanitary, safety codes and National Electrical Code.

Plumbing Notes: Because of the variation in house-supplied steam and water pressures, steam and water pressure regulating valves (PRVs) may be needed (Water PRV is standard on machines with booster). The PRVs can either be purchased from Hobart or obtained locally.

Gas Heat Only: For natural gas, pressure to the burner (customer connection) should be 3.5" minimum, 7" maximum W.C.

For LP gas, pressure to the burner (customer connection) should be 8" minimum, 11" maximum W.C.

If gas pressure is higher than 7" (Natural) or 11" (LP) W.C., a pressure regulating valve must be installed (by others) in the gas line to the dishwasher.

SPECIFICATIONS

Capacities

Racks per Hour (NSF rated)	342
Wash Tank (U.S. gallons)	23
Rinse Tank (U.S. gallons)	22
Power Scrubber (U.S. gallons)	23
Conveyor Speed (feet per minute)	9.5

Motor Horsepower

Drive	1/6
Wash	.2
Power Scrubber	.2
Rinse	.2

Water Consumption

U.S. Gallons per Hour (maximum use)	132
U.S. Gallons per Rack	0.39

Heating

Electric Booster (built-in) (kW for 40°F rise)	15
Electric Booster (built-in) (kW for 70°F rise)	30

Heating Equipment (for wash tank heat)

Gas Burners (L.P. or natural gas)	
BTU per Hour	156,000

Venting

Load End (minimum CFM)	200
Unload End (minimum CFM)	400
(Gas exhaust venting must be installed according to local code)	

Shipping Weight (approximate) 991 lbs.

Crated Dimensions 96"L x 38"W x 78"H

E1	Electrical Connection (3 PH only) Motor, Power Wash Tank and Controls			
	Voltage	Rated Amps	Minimum Supply Circuit Ampacity	Maximum Protective Device
	208/60/3	24.1	35	35
	240/60/3	24.1	35	35
	480/60/3	13.1	20	20

CLPS86eN-BAS Gas Heat Dissipation	
BTU/HR.	
Latent	Sensible
50,000	21,400
Note: Additional heat dissipation information available on F40459.	



CLPS86eN-BAS GAS

High Temperature Rack Conveyor
Dishwashing Machine

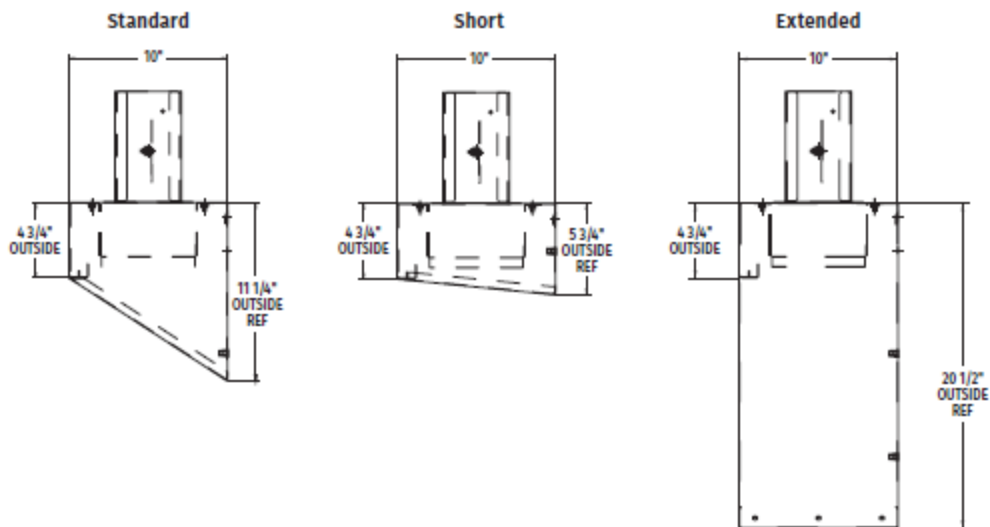
E2	Booster Heat 30 kW (Standard) Minimum 110°F Incoming Water		
Voltage	Rated Amps	Minimum Supply Circuit Ampacity	Maximum Protective Device
208/60/3	83.9	90	90
240/60/3	80.2	90	90
480/60/3	40.1	50	50

E2	Booster Heat 15 kW (Field Convertible) Minimum 140°F Incoming Water		
Voltage	Rated Amps	Minimum Supply Circuit Ampacity	Maximum Protective Device
208/60/3	45.0	60	60
240/60/3	40.1	50	50
480/60/3	20.0	25	25

COMMON ELECTRICAL CONNECTION (SINGLE POINT) – CONTACT FACTORY FOR ADDITIONAL INFORMATION

Common Electrical Connection (Includes Motors & Controls, and Electric Booster Heater)						
Voltage	MACHINE AND 15kW BOOSTER			MACHINE AND 30kW BOOSTER		
	Rated Amps	Minimum Supply Circuit Ampacity	Maximum Protective Device	Rated Amps	Minimum Supply Circuit Ampacity	Maximum Protective Device
208/60/3	69.1	90	90	108	125	125
240/60/3	69.1	90	90	108	125	125
480/60/3	33.1	45	45	53.2	70	70

VENT HOOD OPTIONS



As continued product improvement is a policy of Hobart, specifications are subject to change without notice.