Food Service
Technology Center

CMA EST-AH / CMA EST-AH with Temp-Sure Heat Recovery Dishwashing Machine Expanded Test Report

FSTC Report # 501311169-R0

Application of ASTM
Standard Test Method F1696-07 and F2474-09

January 2014

Prepared by:
Denis Livchak
Rich Swierczyna
Fisher-Nickel, Inc.

Prepared for:
Pacific Gas and Electric Company
Customer Energy Efficiency Programs
PO Box 770000
San Francisco, California 94177

FSTC Equipment Test Report

Food Service Technology Center Background

The information in this report is based on data generated at the Pacific Gas and Electric Company (PG&E) Food Service Technology Center (FSTC). Dedicated to the advancement of the foodservice industry, The FSTC has focused on the development of standard test methods for commercial foodservice equipment since 1987. The primary component of the FSTC is a 10,000 square-foot laboratory equipped with energy monitoring and data acquisition hardware, 60 linear feet of canopy exhaust hoods integrated with utility distribution systems, equipment setup and storage areas, and a state-of-the-art demonstration and training facility.

The FSTC Energy Efficiency for Foodservice Program is funded by California utility customers and administered by PG&E under the auspices of the California Public Utilities Commission (CPUC). California customers are not obligated to purchase any additional services offered by the contractor.

Policy on the Use of Food Service Technology Center Test Results and Other Related Information

• Fisher-Nickel, Inc. and the FSTC do not endorse particular products or services from any specific manufacturer or service provider.

• The FSTC is *strongly* committed to testing foodservice equipment using the best available scientific techniques and instrumentation.

• The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.

• FSTC test results are made available to the general public through technical research reports and publications and are protected under U.S. and international copyright laws.

Disclaimer

 Results relate only to the item(s) tested. Neither, Fisher-Nickel, Inc., PG&E nor any of their employees, or the FSTC, make any warranty, expressed or implied, or assume any legal liability of responsibility for the accuracy, completeness, or usefulness of any data, information, method, product or process disclosed in this document, or represents that its use will not infringe any privately-owned rights, including but not limited to, patents, trademarks, or copyrights.

Reference to specific products or manufacturers is not an endorsement of that product or manufacturer by Fisher-Nickel, Inc., the FSTC, or PG&E. In no event will Fisher-Nickel, Inc. or PG&E be liable for any special, incidental, consequential, indirect, or similar damages, including but not limited to lost profits, lost market share, lost savings, lost data, increased cost of production, or any other damages arising out of the use of the data or the interpretation of the data presented in this report.

Retention of this consulting firm by PG&E to develop this report does not constitute endorsement by PG&E for any work performed other than that specified in the scope of this project.

Legal Notice

This report was prepared as a result of work sponsored by the California Public Utilities Commission (CPUC). It does not necessarily represent the views of the CPUC, its employees, or the State of California. The CPUC, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the use of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the CPUC nor has the CPUC passed upon the accuracy or adequacy of the information in this report.

Revision History

Revision num.	Date	Description	Author(s)
0	Jan 2014	Initial Release	R. Swierczyna / D. Livchak

Contents

Figures

Tables

Executive Summary

Door-type dishwashing machines have become common appliances in small to medium commercial kitchens. As one of the biggest consumers of hot water and typically requiring dedicated ventilation and cooling, door-type dishwashing machines have become a major contributor to the total restaurant energy usage. Ventless heat recovery dishwashing machines have become a viable alternative to installing a Type II exhaust hood or directly venting the unit (depending on local code jurisdiction), thereby reducing the energy load on the restaurant's water heater due to heat recovery capabilities. This report will discuss the energy and water usage as well as the space cooling and ventilation requirements for standard and ventless heat recovery door-type low temp dishwashing machines.

Figure 1: CMA EST-AH standard low temp dump and fill machine

The CMA EST-AH (Figure 1) is a door-type low temp chemical sanitizing dump and fill electric dishwashing machine. A heat recovery version of this machine CMA-EST-AH with Temp Sure (Figure 2) utilizes a fan and motor that condenses the wash cycle vapor and forces it through a heat exchanger to preheat the incoming cold water supply. The heat recovery version with Temp Sure also has a booster heater to raise incoming cold water up to temperature. To determine dishwashing machine performance, FSTC engineers used modified ASTM F1696-07 *Standard Test Method for Performance of Single Rack, Door-Type Commercial Dishwashing Machines*[1] and ASTM F2474-09 *Standard Test Method for Heat Gain to*

[1] American Society for Testing and Materials. 2007. *Standard Test Method for Performance of Single Rack, Door-Type Commercial Dishwashing Machines.* ASTM Designation F1696-07, in *Annual Book of ASTM Standards*, West Conshohocken, PA.
[2] American Society for Testing and Materials. 2009. *Standard Test Method for Heat Gain to Space Performance of Commercial Kitchen Ventilation/Appliance Systems.* ASTM Designation F2474-09, in *Annual Book of ASTM Standards*, West Conshohocken, PA.

Space Performance of Commercial Kitchen Ventilation/Appliance Systems [2]. Dishwashing machine performance is characterized by preheat and idle energy consumption rate, washing energy and water rate per rack and production capacity. Washing energy rate and production capacity was determined by washing racks of ten plates in succession while maintaining the required minimum wash tank temperature. The CMA EST-AH dishwashing machine achieved a washing energy rate of 29 wh/rack while washing 30 racks per hour with incoming 140°F hot water. There was no idle energy, because the dishwasher did not have any heating elements. The CMA EST-AH with Temp Sure heat recovery dishwashing machine achieved a washing energy rate of 200 wh/rack while washing 24 racks per hour with incoming cold water at 73°F; the idle energy rate of the booster heater was 105W.

Figure 2: CMA EST-AH Temp Sure Ventless Heat Recovery System

Dishwashing machine heat gain to space is characterized by latent and sensible heat loading. The total convective heat gain to space for the CMA EST-AH standard unit was measured as 8.5 kBtu/h, which included a 2.6 kBtu/h sensible load and 5.9 kBtu/h latent load. The total heat gain to space for the CMA EST-AH with Temp Sure heat recovery unit was measured as 8.3 kBtu/h, which included a 2.4 kBtu/h sensible load and 5.9 kBtu/h latent load. A summary of the test results is presented in Table 1.

Table 1: Summary of CMA EST-AH Rack Dishwashing Machine Performance and Heat Loading

Appliance	CMA EST-AH	CMA EST-AH with Temp Sure
Rated Input (kW)	1.8	1.8+9.0
Measured Maximum Energy Rate (kW)	1.5	1.8+9.5
Fill and Preheat Time (min)	0	3.75
Preheat Energy Consumption (kWh)	0	0.58
Idle Energy Rate (W)	0	105
Washing Energy Rate (kW)	0.88	4.79
Washing Energy Rate (Wh/rack)	29	200
Washing Water Consumption (gal/rack)	1.15	1.10
Production Capacity (racks/hr)	30	24
Total Convective Heat Gain to Space (kBtu/h)	8.5	8.3
Sensible Heat Load (kBtu/h)	2.6	2.4
Latent Heat Load (kBtu/h)	5.9	5.9

Introduction

Background

Low temp dump and fill door-type dishwashing machines have become a necessity in today's high production commercial kitchen. These machines are able to wash and sanitize various types of wares and utensils consistently at a medium volume. Low temp dump and fill dishwashers do not have a large tank compared to conventional tank dishwashers. The small reservoir in a dump and fill dishwasher is called a sump and usually holds only the amount of water required to wash a single rack (1-2 gal). Dump and fill dishwashers do not require a heater for the tank, eliminating standby energy. The heated water from the previous rinse cycle is used for the wash cycle of the next. During the rinse cycle, the wash cycle water is dumped and the dishwasher is filled with fresh rinse water at 140°F. Low temperature dishwashers usually require 140°F incoming water in order to dissolve grease. The low temperature sanitizing is achieved with the use of additional chemicals (i.e., chlorine) that are not required for high temp machines. Utilizing 140°F low temperature water instead of 180°F sanitization temperature required for high temperature dishwashers requires less energy for water heating allowing for lower amperage electrical service. The energy demand on the water heater is slightly increased, with dump and fill dishwashers usually consuming slightly more water per rack.

Ventilation has been a major issue with high temp dishwashing machines sometimes requiring a separate Type II ventilation hood and a rooftop fan to capture the steam generated by the machine to reduce the heat and humidity in the kitchen. Low temp dishwashers usually generate less steam than the high temp units, because of a lower operating temperature, therefore generating less heatgain to the space than their high temp counterparts. Ventilation requirements for low temp dishwashers vary based on building and mechanical codes by region and jurisdiction. Ventless heat recovery dishwashing machines have been new to the foodservice industry market and provide an alternative to installing a dishwashing machine with an external ventilation system. Heat recovery dishwashing machines also utilize cold water, significantly reducing the water heating load of the restaurant.

The ASTM designation ASTM F1696-07 *Standard Test Method for Performance of Single Rack, Door-Type Commercial Dishwashing Machines* characterizes dishwashing machine performance by evaluating its energy and water consumption, washing production capacity and idle energy rate. ASTM appliance performance can be used to estimate an appliance's contribution to the energy consumption of an end-user's kitchen. The ASTM designation F2474-09 *Standard Test Method for Heat Gain to Space Performance of Commercial Kitchen Ventilation/Appliance Systems* characterizes dishwashing machine performance by measuring the heat gain from the appliance into the space.

The glossary in Appendix A is provided so that the reader has a reference to the terms used in this report.

Objectives

The objective of this report is to examine the operation and performance of the CMA EST-AH door-type dishwashing machine with and without Temp Sure Ventless Heat Recovery under the controlled conditions of the ASTM designation F1696-07 *Standard Test Method for Performance of Single Rack, Door-Type Commercial Dishwashing Machines*, and ASTM designation F2474-09 *Standard Test Method for Heat Gain to Space Performance of Commercial Kitchen Ventilation/Appliance Systems*. The scope of this testing is as follows:

1. Verify that the appliances are operating at the manufacturer's rated energy input.
2. Verify that the appliances are operating at the NSF's rated water consumption rate.
3. Determine the time and energy required to fill and preheat the dishwashing machine from incoming water temperature to minimal operational wash temperature and until the tank heater elements cycle off.
4. Characterize the dishwashing machine's idle energy use.
5. Determine the dishwashing machine's washing energy rate under a specified ASTM dish loading scenario.
6. Determine the dishwashing machine's production capacity for the ASTM dish loading scenario while maintaining minimum wash tank temperature.
7. Determine the sensible and latent heat gain to space of the dishwashing machine.

Appliance Description

The CMA EST-AH is an electric, low temp, dump and fill, door-type dishwashing machine with a rated input of 1.8 kW and a sump capacity of one gallon. The pump motor circulates the water from the previous rinse cycle during the wash cycle through two rotating nozzle arms located above and below the dish rack (Figure 3). The washing cavity has a valve that opens at the end of the wash cycle allowing the water into the sump with a temperature gauge attached to it (Figure 4). The front panel has an on/off switch as well as auto fill button; there is a wash cycle counter behind the front panel. The CMA EST-AH with Temp Sure is a ventless heat recovery version of the CMA EST-AH dishwashing machine that features a heat exchanger to transfer heat generated by the wash cycle steam to the incoming cold water. The heat recovery dishwashing machine also features a built in booster heater rated at 9 kW and with electric resistance heating element operating at 208V. At the end of each rinse cycle, the heat recovery fan condenses the steam in the washing cavity by forcing it through a heat exchanger, preheating the incoming cold water. The CMA EST-AH with Temp Sure Heat Recovery has a cold and a hot water connection, whereas the CMA EST-AH standard machine has a hot water connection only. For the heat recovery machine, the hot water connection is used to flush the condensing heat exchanger once the machine is turned off. The incoming cold water is used for the rinse cycle; it is first preheated by the condensing heat exchanger and later by the internal booster heater to achieve temperatures above 140°F. Using cold incoming water reduces the load on the restaurant's external water heater and steam condensation heat recovery reduces the heat and moisture loading

Figure 3: CMA EST-AH Washing Cavity: Lower Wash and Rinse Arms

Figure 4: CMA EST-AH sump reservoir beneath the washing cavity

to the kitchen space as compared to a standard dishwasher. A summary of the dishwasher specifications is presented in Table 1.

Table 2: CMA EST-AH Appliance Specifications

Appliance	Door-type High Temp Dishwashing Machine	
Manufacturer	CMA	
Model	EST-AH	EST-AH with Temp Sure
Serial Number	212550	212105
Generic Appliance Type	Door-type Low Temperature Dump and Fill Dishwashing Machine	
Total Rated Input	1.8 kW	10.8 kW
Booster Input	NA	9.0 kW
NSF Rated Rinse Water Consumption	1.09 gal/rack	1.09 gal/rack
Specified Wash Tank Volume	NA	
Operating Voltage	115 V	115V and 208V booster
Minimum Rated Wash Temperature	120 F	
Minimum Rinse Temperature	120 F	
Controls	On/Off; Autofill; Analog sump temperature gauge	
Construction	Stainless steel	
Washing Cavity Dimensions (W x D x H)	20" x 20" x 17.5"	
External Dimensions (W x D x H)	25.8" x 25.8" x 73.5"	25.8" x 25.8" x 86"

Methods and Results

Setup and Instrumentation

FSTC researchers installed the dishwashing machine in a ventilation lab that was airtight. The dishwashing machine was placed on the floor with a 12 inch rear clearance to allow for drain connections. The dishmachine was placed under a Type II, 5-foot wide, 4-foot deep wall-mounted canopy hood that was hung 6 feet-6 inches above the floor. Side-panels were installed on the hood and all the filters removed (Figure 3). The floor-drain was connected to the machine by PVC pipe.

Three temperature trees were spaced three feet apart, six feet from the back of the hood to monitor the makeup air temperature entering the room. Each tree had three Resistance Temperature Detectors (RTD's) shielded from radiation at the height of 37, 55 and 72 inches with low airflow fans to maintain a constant velocity airstream over the temperature sensors.

The CMA EST-AH dishwashing machines were installed in accordance with the manufacturer's instructions in a conditioned test space. The room was maintained at an ambient condition of 75 ± 5°F during testing. Dishwashing machine energy was measured with equipment listed in Table 3.

Figure 5: CMA EST-AH with Temp Sure Dishwashing Machine with Installed under the 5 ft hood

Table 3: Testing Equipment Inventory

Equipment Type (ID)	Manufacturer	Model	Measurement Range	Resolution	Calibration Date	Next Calibration Date
High Current 208V electric meter (ALC 301)	Electro Industries	Shark 200	0.1 A – 75 A	7.5 Wh	11/21/12	11/21/13
Low Current 120V electric meter (ALC 305)	Radian Research	RM-10	0.2 A – 50 A	0.00001 Wh	12/12/12	12/12/13
Water Meter (O-WM109)	Omega	K: 550	0 – 13 GPM	550 pulses / gal.	(Verified Internally) 10/02/13	NA

Submerged Type K thermocouples were used to measure the incoming water supply (Figure 6), and sump temperature at the bottom of the tank on both dishwashing machines (Figure 7). Low voltage electric energy was measured using a true energy watt hour energy meter and high voltage booster heater energy for the CMA EST-AH with Temp Sure Heat Recovery was measured using three-phase current transducer meter for the dishwashing machine. The dishwasher's water consumption was measured using a verified mechanical paddle wheel style water meter that generated digital pulses and were output to the computer. For the CMA EST-AH with Temp Sure Heat Recovery both hot and cold incoming water volumes were monitored. The transducers and thermocouple probes were connected to a computerized data acquisition unit that recorded data every five seconds.

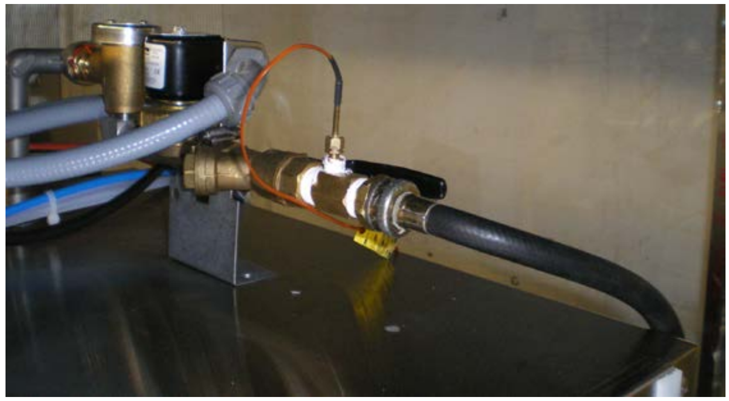


Figure 6: CMA EST-AH incoming water temperature measurement location

The hood exhaust temperature was measured using an array of 12 RTD's downstream from the hood and the supply flow rate was measured using a 16-inch diameter pitot-tube array differential pressure flow station A separate computer was used to log the exhaust and supply airflow rates, lab pressure differential, makeup air temperatures and exhaust temperatures at an interval of five seconds for the heat gain calculations.

Measured Energy and Water Input Rate Test

Rated energy input rate is the maximum or peak rate at which the dishwashing machine consumes energy as specified on the manufacturer's nameplate. Measured energy input rate is the maximum or peak rate of energy consumption, which is recorded during a period when the wash or rinse pump is on. For the CMA EST-AH with Temp Sure Heat Recovery booster Heater energy input rate was measured during the preheat period from room temperature. This procedure ensured that the dishwashing machine was operating within its specified parameters. The 115V measured energy input rate of the dishwashing machine was 1.5 kW for the standard CMA EST-AH version

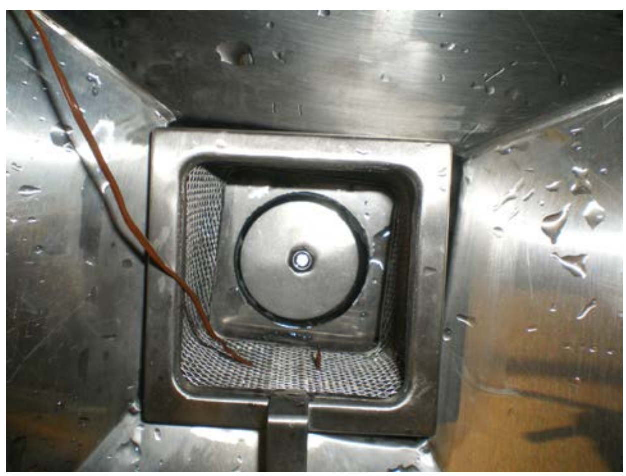


Figure 7: CMA EST-AH Washing Cavity Temperature Location Representative of the Sump Temperature

and 1.8 kW for the CMA EST-AH with Temp Sure Heat Recovery machine which was measured during the rinse cycle. The 208V measured energy input rate of the CMA EST-AH with Temp Sure Heat Recovery machine was found to be 9.5 kW. This energy consumption was within 5% from the nameplate rating. The water consumption of a dishwashing machine washing a single rack is tested by NSF and listed on the manufacturer's nameplate. The internal rinse cams can be adjusted based on the potable water pressure to achieve the NSF water consumption rate. The rinse cycle fill time was adjusted to achieve a NSF rated water consumption of 1.09 gallons per rack for the CMA EST-AH machine. This water consumption was adjusted to 1.15 gallons per rack to be within 5% from the nameplate rating. The CMA EST-AH with Temp Sure machine was adjusted to consume 1.10 gallons per rack, which is within 1% of the 1.09 gallon per rack nameplate rating. Table 4 summarizes the results from the input test.

Preheat and Idle Tests

Conventional low temperature dump and fill machines do not have any heating elements and no tank, so there is no preheat. The incoming hot water into the machine is the only source of heat for the machine. Conventional low temperature dump and fill machines also have almost no standby energy (only the energy consumed by the controls which is very small) because there is no tank with to keep at a certain temperature. This is the case with the standard CMA EST-AH machine which has no preheat or idle energy consumption.

The CMA EST-AH with Temp Sure utilizes a booster heater in order to heat up cold water that has passed through the heat recovery exchanger up to 140°F. The booster heater has a volume of approximately 2 gallons with 208V resistance heating elements rated at 9 kW. The booster heater must maintain its temperature throughout the day in order to be able to provide 140°F water for the rinse cycle consistently. The idle rate of the booster heater was determined to be 105W which was averaged over five 3 hour intervals.

The CMA EST-AH with Temp Sure's booster heater is always filled with water, because if the heating elements energize unsubmerged, they may beocome damaged. The booster heater takes 3.75 minutes and 576 wh to preheat from room temperature to operational setpoint of 140°F. Time and energy were measured from the time the machine was turned on until the heating elements cycled off. A was cycle was then engaged to verify that the sump temperature was over 120°F.

Once the CMA EST-AH with Temp Sure is turned off, it uses hot water to flush the condenser in order to clear it of any grease deposition. This process takes half a minute and requires 1.83 gallons of hot water and does not require any diswasher energy. Preheat and idle test results are shown in Table 4.

Table 4: Input, Preheat, and Idle Test Results for the CMA EST-AH Door-type Dishwashing Machine

Appliance	CMA EST-AH	CMA EST-AH with Temp Sure
Rated 115V Energy Input Rate (kW)	1.8	1.8
Rated 208V Booster Energy Input Rate (kW)	-	9.0
Measured Energy Input Rate (kW)	1.5	11.3
Percentage Difference (%)	17	5
Preheat Duration (min)	-	3.75
Preheat Electric Energy Consumption (Wh)	-	576
Preheat Temperature at location (°F)	-	139.8
Booster Heater Electric Idle Energy Rate (W)	-	105

Washing Tests

Standard dish racks weighing 4.1 lbs were used for this test and were loaded with ten evenly spaced plates averaging 1.35 lbs. The washing test consisted of washing 20 racks loaded with 10 dishes in succession allowing half a minute between the end of the cycle and the start on the next one to replace the racks of dishes with room temperature ones. The dishwasher was stabilized prior to the test by washing several racks of dishes until the exhaust temperature has stabilized. The dishwasher door was opened as soon as the wash cycle light went off. The washed rack of plates was replaced with a new room temperature rack of 10 plates within 30 seconds. A total of 20 racks were washed. For the CMA EST-AH standard, the wash and rinse cycle took 1.5 minutes to complete and the dish rack swap took another 0.5 minute for a total of a 2 minute cycle for the test (Figure 8). For the CMA EST-AH with Temps Sure heat recovery, the wash and rinse cycle took 1.5 minutes to complete, the condensing heat recovery cycle took 0.5 minutes and the dish rack swap took another 0.5 minute for a total of a 2.5 minute cycle for the test (Figure 9). 15 racks of plates were washed for a full test of the CMA EST-AH with Temps Sure heat recovery. The maximum sump temperature during each rinse cycle for both dishwashers was maintained above 120°F throughout the entire test. Figure 10 and 11 shows the sump temperature profile during the entire test for both dishwashers.

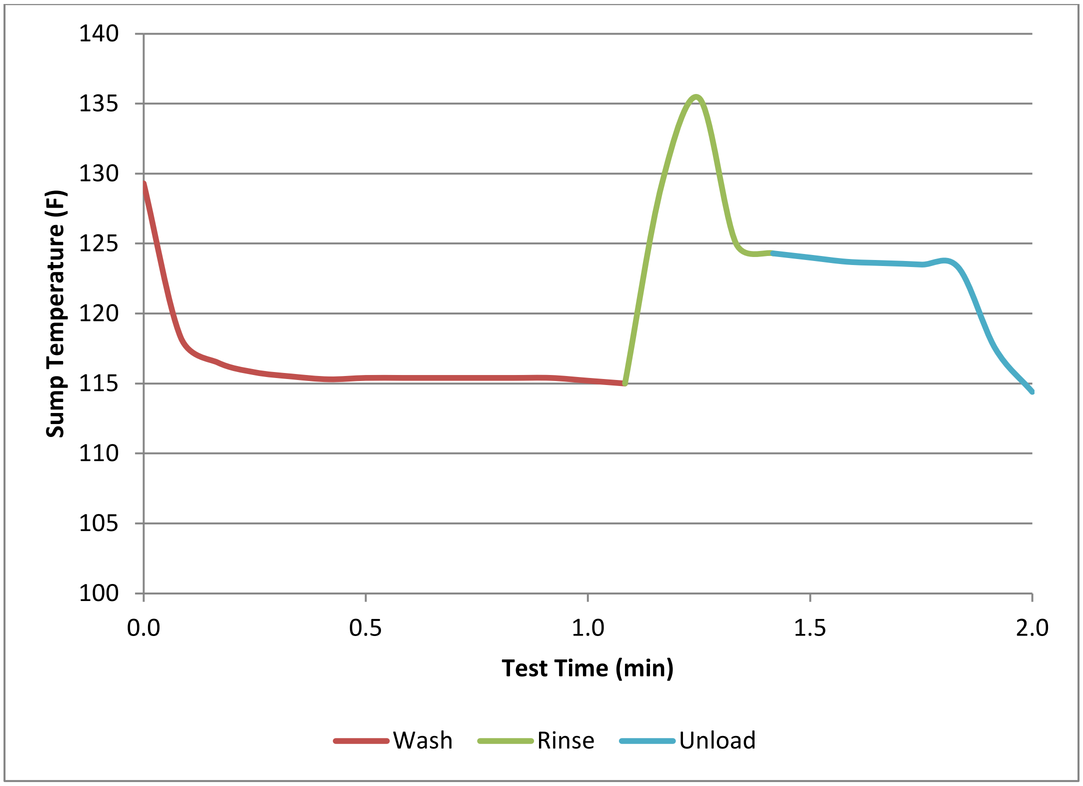


Figure 8: CMA EST-AH Standard Dishwashing Machine Single Load Temperature Test Profile

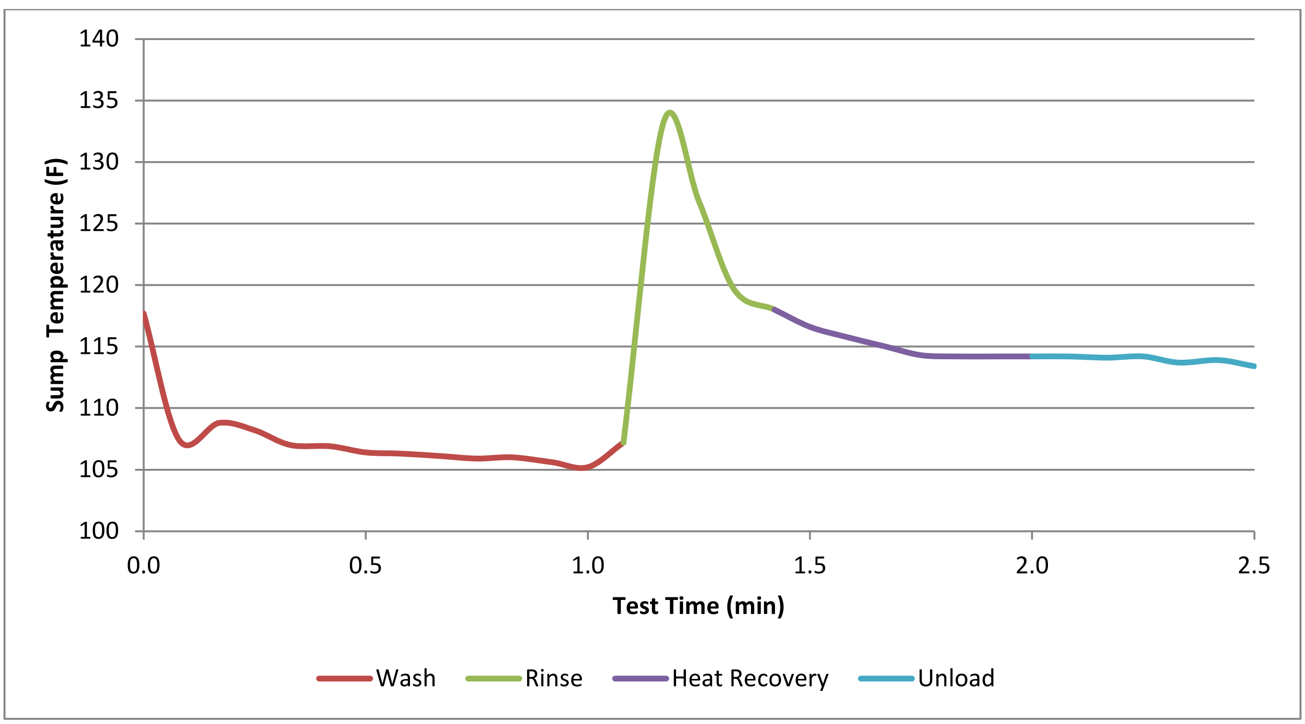


Figure 9: CMA EST-AH with Temp Sure Heat Recovery Single Load Temperature Test Profile

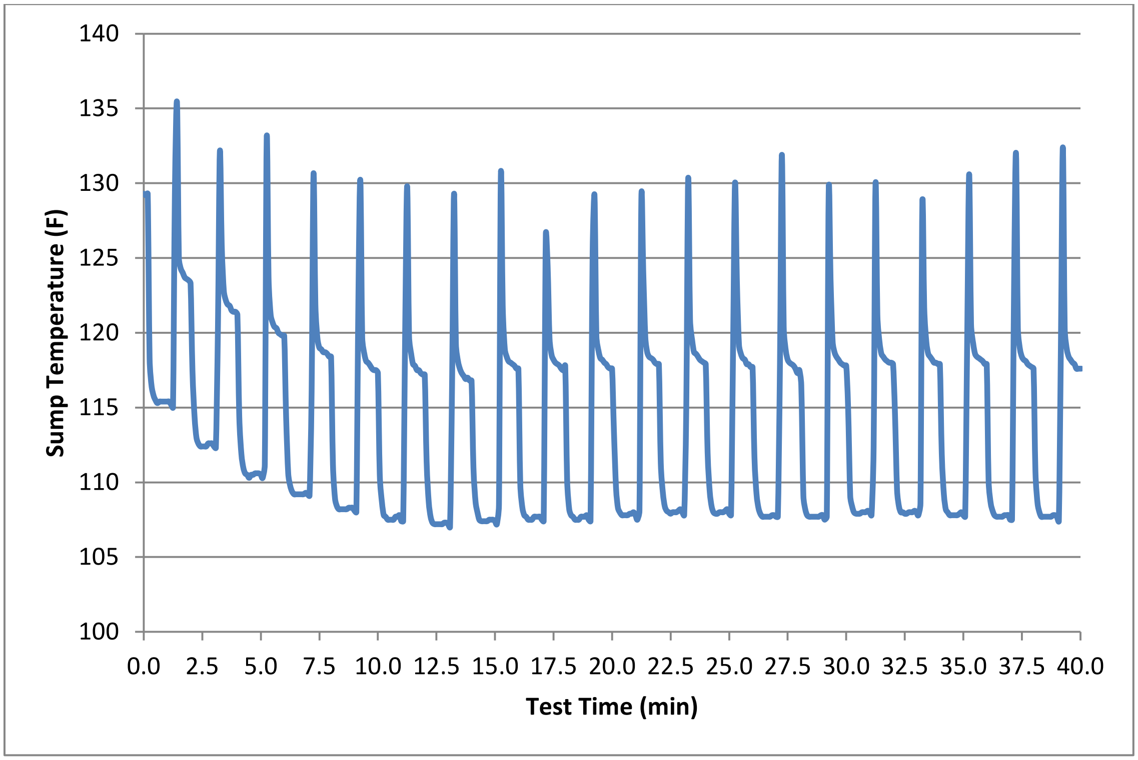


Figure 10: CMA EST-AH Standard Dishwashing Machine Sump Temperature Test Profile

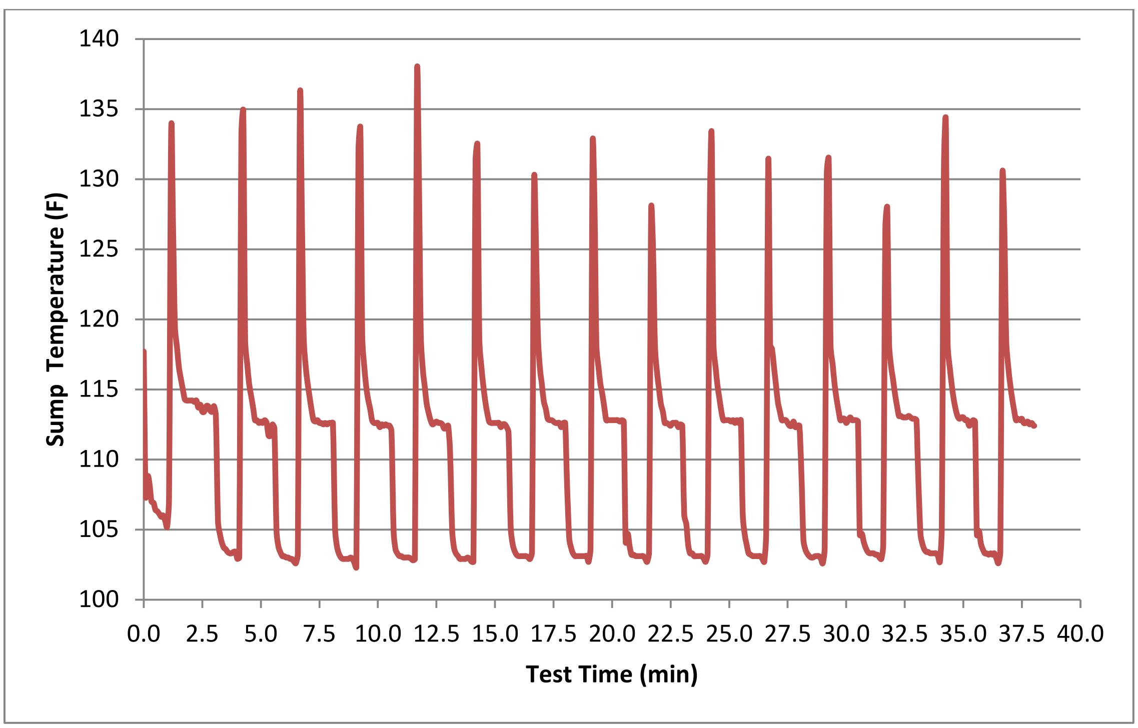


Figure 11: CMA EST-AH with Temp Sure Heat Recovery Dishwashing Machine Sump Temperature Test Profile

Total dishwasher energy, booster heater energy and water consumption was recorded for each test run. The CMA EST-AH standard dishwashing machine demonstrated an average washing energy rate of 0.88 kW throughout the entire test. The production capacity for the dishwasher was 30 racks per hour including 30 sec unloading and loading time. The CMA EST-AH with Temp Sure heat recovery dishwasher energy included the heat recovery fan motor which turned on for 30 seconds after the rinse cycle. The CMA EST-AH with Temp Sure heat recovery dishwashing machine had a production capacity of 24 racks per hour (including 30 sec unloading and loading time) operating at an average wash energy rate of 4.79 kW. CMA EST-AH standard used 29 wh of pump energy during each wash and rinse cycle using 138°F incoming water. CMA EST-AH with Temp Sure heat recovery used 200 wh of pump, fan and booster energy per rack washed using 73°F incoming water. Gas water heating energy was calculated for CMA EST-AH standard machine to bring up the water volume used for the washing test from 73°F to 138°F at 65% water heater efficiency which was 955 Btu/rack. Table 5 summarizes the results from the dishwashing tests.

Table 5: CMA EST-AH Dishwashing Machine Washing Energy Rate and Production Capacity Test Results

Appliance	CMA EST-AH	CMA EST-AH with Temp Sure
Total Washing Energy Rate (kW)	0.88	4.79
Total Washing Energy Rate (Wh/rack)	29	200
Gas Water Heating Energy (Btu/rack)	955	0
Washing Water Consumption (gal/rack)	1.15	1.10
Average Supply Water Temperature (°F)	138	73
Average Rinse Water Temperature (°F)	122	132
Production Capacity (racks/hr)	30	24

Energy Consumption Model

The test results can be used to estimate the annual energy consumption for the CMA EST-AH door type low temp dump and fill dishwashing machine in a real-world operation. A simple energy consumption model was developed to calculate the energy consumption from the various components (e.g., preheat, idle, water heating and washing) using the ASTM test data (see Equations 1 and 2 below). Any chemical costs such as detergent are not included in these calculations. Water heating costs are estimated assuming 65% gas water heater efficiency and 65°F temperature rise, specific weight of water is assumed to be 8.29 lb/gal at an average temperature of 105°F between 73°F and 138°F using Equation 3.

$$\mathrm{E}_{\mathrm{elec,\,daily}} = \mathrm{E}_{\mathrm{elec,\,h}} + E_{elec,\,i} + \left(n_p \times E_{elec,\,p}\right) \qquad \text{(Equation 1)}$$

$$\mathrm{E}_{\mathrm{elec,\,h}} = \frac{\mathrm{W}}{\mathrm{PC}} \times q_{elec,\,h} \qquad = \qquad \mathrm{E}_{\mathrm{elec,\,h}} = \mathrm{W} \times \mathrm{WPR}$$

$$\mathrm{E}_{\mathrm{elec,\,i}} = q_{elec,\,i} \times \left(t_{on} - \frac{\mathrm{W}}{\mathrm{PC}} - \frac{n_p \times t_p}{60} \right)$$

$$\mathrm{E}_{\mathrm{elec,\,daily}} = \frac{\mathrm{W}}{\mathrm{PC}} \times q_{elec,\,h} + \left(q_{elec,\,i} \times \left(t_{on} - \frac{\mathrm{W}}{\mathrm{PC}} - \frac{n_p \times t_p}{60} \right) \right) + \left(n_p \times E_{elec,\,p}\right) \qquad \text{(Equation 2)}$$

$$\mathrm{E}_{\mathrm{gas\ water\ heating,\,daily}} = 8.29 * \mathrm{W} * \mathrm{GPR} * 65 / 0.65 \qquad \text{(Equation 3)}$$

Where:

$E_{elec,daily}$	=	Daily energy consumption (kWh)
W	=	Number of racks washed per day
PC	=	Heavy Load Cycle Rate (racks/hr)
$q_{elec,h}$	=	Washing and Booster energy rate (kW)
$q_{elec,i}$	=	Idle energy rate (kW)
t_{on}	=	Total time the appliance is on per day (hr)
n_p	=	Number of preheats per day
t_p	=	Duration of preheat (min)
$E_{elec,p}$	=	Preheat energy (kWh)
$E_{elec,h}$	=	Heavy-load washing energy (kWh)
$E_{elec,i}$	=	Idle energy (kWh)
WPR	=	Kilowatt-hours Per Rack including booster energy (kWh/rack)
GPR	=	Gallons Per Rack

The model is based on a typical full service restaurant, washing 200 racks of dishes over a 14-hour day, one preheat cycle per day, 364 days per year (excluding one holiday per year). The HVAC costs of a dedicated ventilation system were not included in the model because the associated heat loads from the dishwashers should be absorbed within the existing HVAC capacity of a well-designed facility. If the HVAC system is under-sized, the space will become hotter and more humid.

Table 6 summarizes the annual energy consumption for the dishwashing machines.

Table 6: CMA EST-AH Door-type Dishwasher Estimated Energy Consumption

Appliance	CMA EST-AH	CMA EST-AH with Temp Sure
Preheat Energy (kWh/day)	0	0.58
Idle Energy (kWh/day)	0	0.60
Washing Energy (kWh/day)	5.85	39.93
Water Heating Energy (kBtu/day)	191	0
Annual Electric Energy (kWh/year)	2,129	14,962
Annual Gas Water Heating Energy (therms/year)	695	0

Heat Load Tests

These tests determined the heat load to the space from CMA EST-AH Standard low temperature dump and fill machine and the CMA EST-AH with Temp-Sure heat recovery low temperature dump and fill machine. The heat load to space is divided into two components: the convective heat that rises as hot air and steam from the machine and the radiation that is emitted by the hot surface of the machine by virtue of the temperature and emissivity. Convective heat can be further broken down into latent and sensible components to separate the dehumidification load on the space cooling system. For un-hooded appliances such as the low temperature dishwashing machine, both components load the kitchen space. The radiation is typically felt directly on the skin and through the clothing of the operator, whereas the convective heat usually circulates within the space and should be absorbed by the kitchen HVAC system.

The calculations used to determine the amount of convective heat load from the dishwashing machine were derived by applying existing standards. These standards included ASTM F1696-07 *Standard Test Method for Performance of Single Rack, Door-Type Commercial Dishwashing Machines*, and ASTM F2474-09 *Standard Test Method for Heat Gain to Space Performance of Commercial Kitchen Ventilation/Appliance Systems*.

With the dishwashing machine operating under a canopy hood that exhausted outside the laboratory, the dry bulb temperatures, dew point temperatures, and airflow rates were measured for the exhaust and makeup air streams. From these measurements, the enthalpy and heat loads were calculated and averaged over a one-hour period.

The hood operated at a nominal exhaust rate of 1700 cfm in order to ensure complete capture and containment of the thermal plume. Capture and containment of the effluent was visually verified using a schlieren optical system. The lab was airtight for the heat gain tests, and a supply fan provided low velocity air (< 60 fpm) to the room through floor standing displacement diffusers. The supply flow rate was balanced to maintain a pressure differential between the inside and the outside of the lab no greater than 0.01 inches of water throughout any heat gain test.

The laboratory energy balance is shown in Figure 12. The calculations that were applied are shown in Equations (4) through (6).

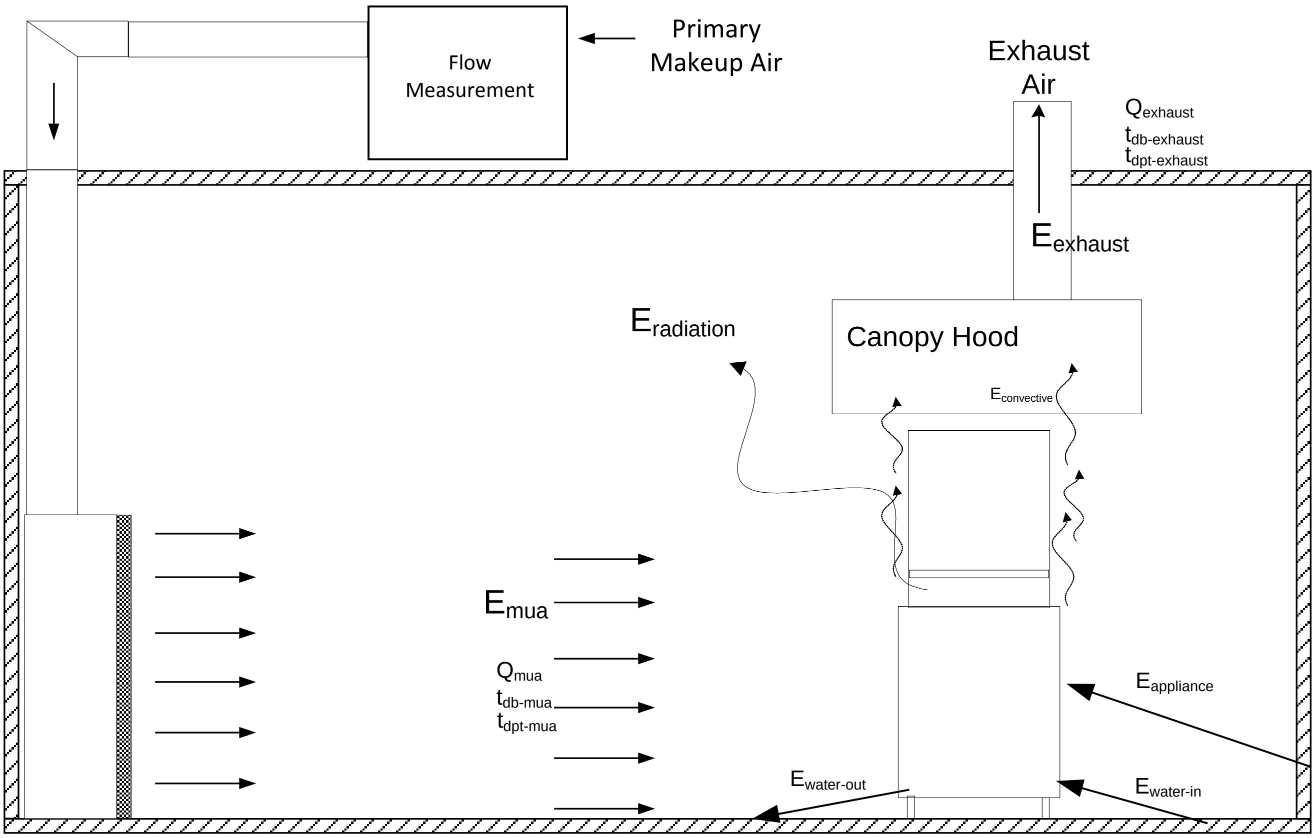


Figure 12: Laboratory Energy Balance Diagram

<u>Energy Balance</u>

$$E_{mua} - E_{exh} - E_{radiation} + E_{appliance} + E_{water\ inlet} - E_{water\ drain} = 0 \quad (4)$$

Where:

E_{mua} is the energy in the makeup air stream
E_{exh} is the energy in the exhaust air streams
$E_{appliance}$ is the energy input to the dishwasher
$E_{water\ inlet}$ is the energy in the makeup hot water to the dishwasher

$E_{water\ drain}$ is the energy in the water overflow from the dishwasher down the drain

The convective heat loads as measured in the exhaust airstream are calculated by:

Convective Loads

$$q_{space\text{-}sensible\ load} = 1.08\ Q_{exh}\ (T_{db\text{-}exh} - T_{db\text{-}mua}) \quad (5)$$

$$q_{space\text{-}latent\ load} = 4840\ Q_{exh}\ (W_{exh} - W_{mua}) \quad (6)$$

Where:

$q_{space\text{-}sensible\ load}$ is the convective sensible heat load to the space in Btu/h
$q_{space\text{-}latent\ load}$ is the convective latent heat load to the space in Btu/h
Q_{exh} is the volumetric flow rate of the exhaust air stream in cfm
$T_{db\text{-}mua}$ the dry bulb temperature of the makeup air stream in °F
$T_{db\text{-}exh}$ is the dry bulb temperature of the exhaust air stream in °F
W_{mua} is the humidity ratio of the makeup air stream in pound of water per pound of dry air
W_{exh} is the humidity ratio of the exhaust air stream in pound of water per pound of dry air

The total heat load (convective and radiant) to the space measured from an un-hooded dishwashing machine is the appliance's measured energy rate (plug load) plus the energy in the supplied water to the unit minus the energy in the drain water. The convective load was calculated directly from the temperature and humidity rise of makeup air to exhaust air conditions and the exhaust flow rate. The convective load was split into sensible and latent components by measuring dew point with a chilled mirror dew point transducer and dry bulb temperatures by using RTD measurement in the makeup and exhaust air streams.

The heat gain to space during idle conditions for the CMA EST-AH Standard machine was negligible since it was tankless and without a booster heater the surface temperatures were near room temperatures during idle conditions. The CMA EST-AH with Temp Sure heat recovery and a booster heater operated at idle rate of 358 Btu/h (105W), which is equal to the heat gain rate during idle conditions.

Heat load tests were also conducted during washing conditions. The dishwasher was stabilized by running five consecutive empty racks. The washing heat load test consisted of washing racks loaded with 10 dishes sequentially. The dishwasher door was opened for 30 seconds as soon as either the rinse cycle or heat recovery cycle ended. The washed rack of plates was replaced with a room temperature rack of plates as quickly as possible. The total cycle time for the CMA EST-AH Standard machine was 2 minutes including a 30 second door open time. The total cycle time for the CMA EST-AH with Temp-Sure heat recovery was 2 minutes and 30 seconds including a 30 second door open time. The sump temperature was maintained above 120°F during the rinse cycle. The convective heat load measurements were separated into sensible and latent energy. The results of the tests are shown in Figure 13.

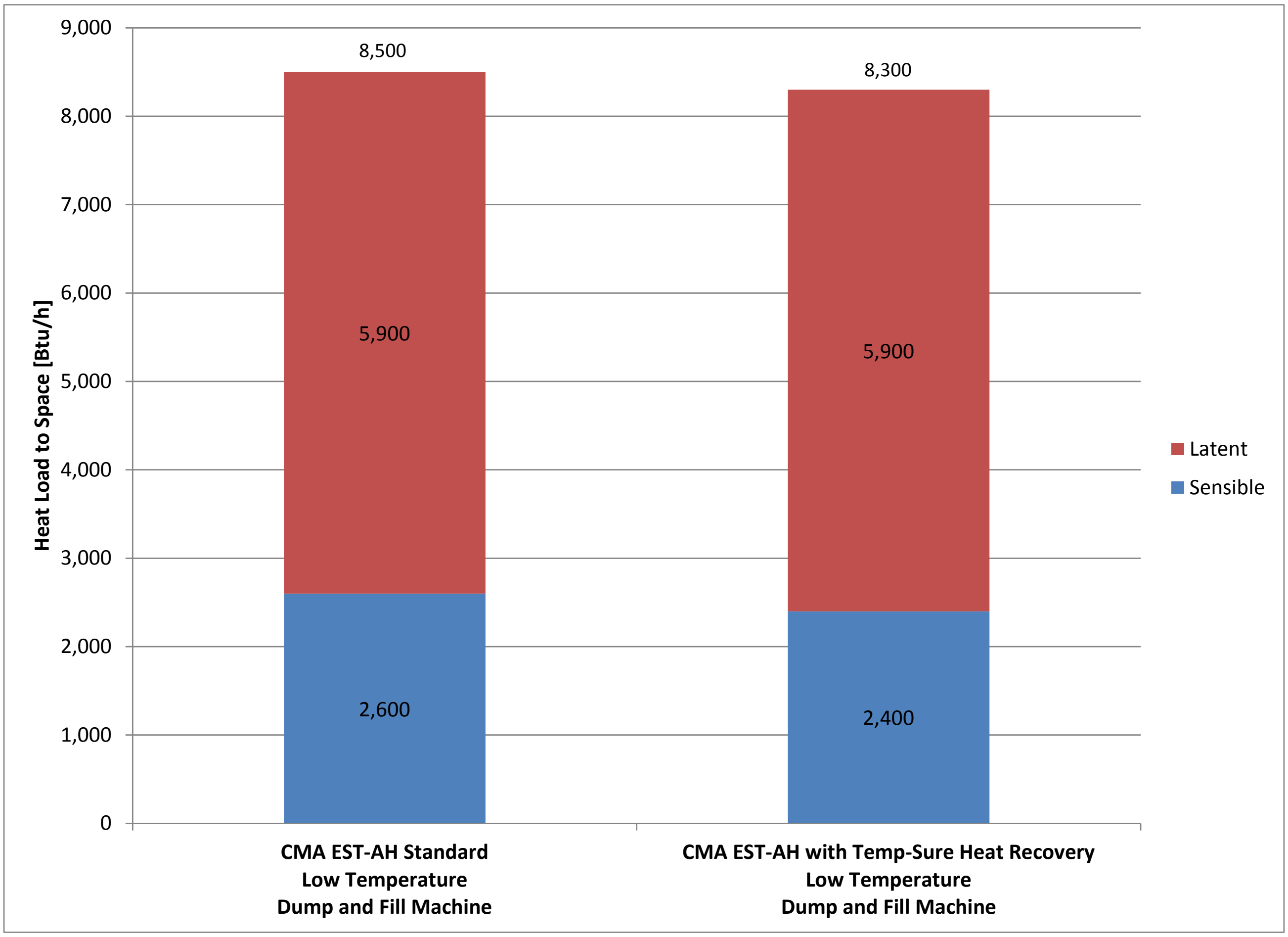


Figure 13: Latent and Sensible Convective Heat Loads During Washing Conditions for the CMA EST-AH Standard Low Temperature and CMA EST-AH with Temp-Sure Heat Recovery Low Temperature Dump and Fill Machines

Comparing the CMA EST-AH Standard low temperature dump and fill machine and the CMA EST-AH with Temp-Sure heat recovery low temperature dump and fill machine, the total convective load was reduced by 200 Btu/h, from 8,500 Btu/h to 8,300 Btu/h during washing tests. A 200 Btu/h reduction in the sensible energy was measured from the low temperature machine with the heat recovery device compared to the Standard low temperature model.

References

[ASTM] American Society for Testing and Materials. 2004. Designation F1361-07: Standard Test Method for Performance of Single Rack, Door-Type Commercial Dishwashing Machines. In: Annual Book of ASTM Standards. Volume 15.12, Livestock, Meat, and Poultry Evaluation Systems; Food Service Equipment. West Conshohocken, PA: ASTM International.

[ASTM] American Society for Testing and Materials. 2009. Designation F2474-09: Standard Test Method for Heat Gain to Space Performance of Commercial Kitchen Ventilation/Appliance Systems. In: Annual Book of ASTM Standards. Volume 15.12, Livestock, Meat, and Poultry Evaluation Systems; Food Service Equipment. West Conshohocken, PA: ASTM International.

[ASHRAE] American Society of Heating, Refrigerating and Air Conditioning Engineers, 2008. Research Project 1362 Revised Heat Gain and Capture and Containment Exhaust Rates from Typical Commercial Cooking Appliances. Atlanta, GA.

Appendix A: Glossary of Terms

Aspirated Temperature Measurement
Temperature measurement with low velocity air flowing over it typically provided by a fan.

CFM
Volumetric flow rate - Cubic Feet per Minute

Convection (kW or Btu/h)
The rate of thermal energy transfer between air in motion and a bounding surface when the two are at different temperatures.

Cooking Energy (Btu, kWh)
The total energy consumed by an appliance as it is used to cook a food product under specified test conditions.

Cooking Energy Rate (kW, Btu/h, or kBtu/h)
Average rate of energy consumption, in hours, during a cooking test.

Dew Point Temperature (°F)
The temperature at which a body of air becomes saturated, holding all the water it can hold. Any further cooling or addition of water vapor results in condensation.

Dry Bulb Temperature (°F)
The temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture.

Effluent
The emissions generated by cooking appliances during their operation, such as convective heat, moisture vapor, products of combustion, smoke and particulate matter.

Emissivity
The relative ability of its surface to emit energy by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature.

Enthalpy
Heat content or total heat, including both sensible and latent heat

FPM
Velocity – Feet Per Minute

Food Product
A type of product (eg. chicken, potatoes) designated by a cooking standard and prepared according to a test method which is used to determine an appliance's cooking performance.

HVAC
Heating Ventilation and Air Conditioning.

Idle Energy Rate (kW or Btu/h)
The rate of energy consumption by an appliance per hour while it is "holding" or maintaining a stabilized operating condition or temperature.

Load, Convective or Radiant
The rate at which heat must be removed from the space to maintain a constant space air temperature.

Measured Energy Input Rate (kW, Btu/h, or kBtu/h)
The peak rate at which an appliance will consume energy, typically measured during preheat (i.e. the period of operation when all burners or elements are "on"). Does not include energy used for appliance controls.

Operative Temperature (°F)
The temperature of the ambient air plus a temperature increment that measures the effectiveness of the incident radiant heating on occupants.

Plug Load
The power requirement of an appliance, usually measured at the plug.

Preheat Energy (kWh, Wh or Btu)
The total amount of energy consumed by an appliance during the preheat period (from ambient temperature to the specified thermostat set point).

Preheat Energy Rate (°F/min)
The rate, in degrees Fahrenheit per minute, at which the appliance increases temperature during preheat.

Preheat Time (min)
The time required for an appliance to heat from the ambient room temperature (75 ± 5°F) to a specified (and calibrated) operating temperature or thermostat set point.

Production Capacity (lb/h)
Maximum rate, in pounds per hour, at which an appliance can bring a specified product to a specified "cooked" condition.

Radiation (kW or Btu/h)
The rate of thermal energy emitted by a surface dependent on its temperature and emissivity.

Rated Energy Input Rate (kW, W or Btu/h)
Maximum or peak rate at which an appliance consumes energy, as rated by manufacturer and specified on the nameplate.

RTD
Resistance Temperature Detector.

Schlieren
Imaging system based on the refractive index of fluids at contrasting temperatures.

Set Point (°F)
Targeted temperature set by appliance controls.

Test Method
A definitive procedure for the identification, measurement and evaluation of one or more qualities, characteristics, or properties of a material, product system, or service that produces a test result.

Typical Day
A sample day of average appliance usage based on observations and/or operator interviews. Used to develop an energy cost model for an appliance.

Uncertainty
Measure of systematic and precision errors in specified instrumentation, or measure of repeatability of a reported test result.

Idle Temperature (°F)
The temperature of the cook zone (either selected by the appliance operator or specified for a controlled test) that is maintained by the appliance under an idle condition.

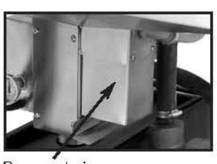
Appendix B: Appliance Specifications

CMA DISHMACHINES

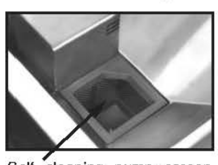
EST/EST-EXT
Chemical Sanitizing
Single Rack
Dishwashers

FEATURES:

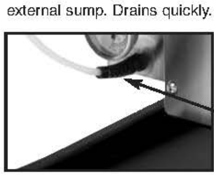
- **ENERGY STAR® Approved.**
- 40 racks / 160 covers per hour.
- Economical to operate. Uses only **1.09** gallons of water per cycle.
- All Stainless Steel construction assures long life and years of trouble free operation.
- Top mounted controls include built-in chemical pumps and deliming system that assures proper chemical usage.
- Power drain saves space, eliminates noisy solenoid and external sump. Drains quickly.
- Available for straight or corner applications.
- Integrated scrap tray prevents food soil from entering drain system.
- Auto start/stop makes operation safe and easy.
- Unique sanitizing system provides instant sanitation and eliminates chlorine damage to the machine.
- Stainless Steel impeller offers extended life.
- Stainless Steel scrap tray, long lasting.
- Water inlet comes with built-in strainer, prevents debris from clogging the water valve.
- Dishmachine comes with 2 dishracks.



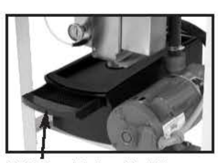
Power drain saves space, eliminates noisy solenoid and external sump. Drains quickly.



Self cleaning pump screen eliminates operator error. Saves service calls.



Unique sanitizing system sanitizer injector is located close to pump, allowing sanitizing to take place immediately. Strategic location eliminates chlorine damage to the machine.



Built-in "Poly Pro"™ scrap accumulator.

Available Options

- Solid/Powder Dual Bowl Dispenser
  Alternative cycle times
  72 Seonds
  2 Minutes
  3 Minutes
- The "TEMP-SURE" requires a seperate 208-240v 3 phase 40 amp power supply.
- Sanitizer Alarm
- Stainless Steel Dishtables
- Alternative Cycle Times
- Alternative Electrical Available
- Stainless Steel Scrap Trap in lieu of Poly Pro
- Slant shelf 21"X42"
- Extended height

Energy MIZER®

ETL | UL LISTED COMMERCIAL DISHWASHER 864T | cUL LISTED COMMERCIAL DISHWASHER 864T | ENERGY STAR | ENERGY STAR PARTNER

CMA Dishmachines 12700 Knott Street Garden Grove, CA 92841 • 800-854-6417 • 714-898-8781 • Fax: 714-895-2141 • www.cmadishmachines.com

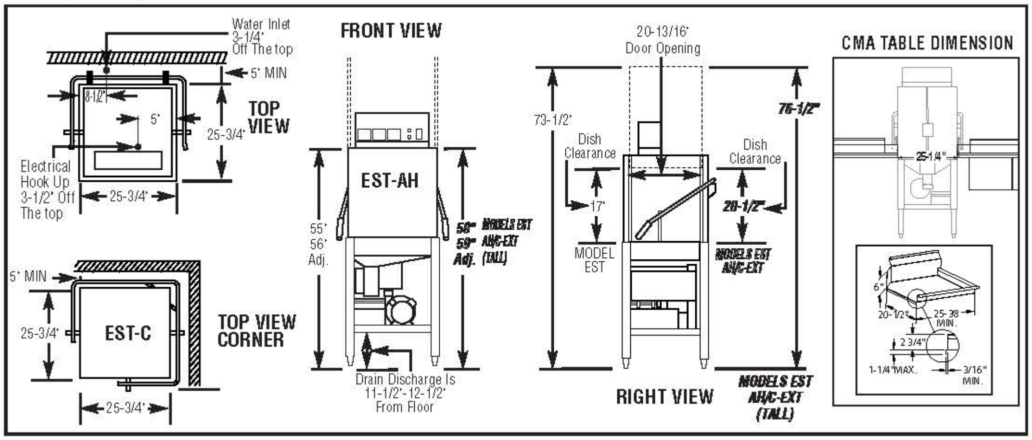
CMA reserves the right to modify specifications or discontinue models without prior notification.

Printed in the U.S.A.

CMA DISHMACHINES

EST/EST-EXT
Chemical Sanitizing
Single Rack
Dishwasher

WARNING: Plumbing connections must be made by a qualified service company who will comply with all available Federal, State, and Local Health, Plumbing and Safety codes.



Specifications:

MODEL EST	USA	METRIC
WATER CONSUMPTION		
PER RACK	1.09 GAL.	(4.12L)
PER HOUR	43.6 GPH	(165 L)
WATER INLET	1/2"	(1.27cm)
DRAIN	2"	(5.1cm)
OPERATING CYCLE		
WASH TIME - SEC.	53	53
RINSE TIME - SEC.	30	30
DWELL	7	7
TOTAL CYCLE	90	90
OPERATING CAPACITY		
RACKS PER HOUR	40	40
WASH TANK CAPACITY	1.09 GAL.	(4.12 L)
PUMP CAPACITY	52 GPM	(197 LPM)
OPERATING TEMPERATURE		
REQUIRED	120°F	(49°C)
RECOMMENDED	140°F	(60°C)

	USA	METRIC
FRAME DIMENSIONS		
DEPTH	25-3/4"	(65.4cm)
WIDTH	25-3/4"	(65.4cm)
HEIGHT	55"-56"	(140cm)
STANDARD TABLE HEIGHT	34"	(86cm)
EST MAXIMUM CLEARANCE HEIGHT FOR DISHES	17"	(43.2cm)
EST-EXT MAXIMUM CLEARANCE HEIGHT FOR DISHES	20-1/2"	(51.4cm)
STANDARD DISHRACK	1	1
DIMENSIONS	19-3/4"X19-3/4"	(50X50cm)
WASH PUMP MOTOR HP	1	1
ELECTRICAL RATING	**VOLTS**	**AMPS**
	115	16
SHIPPING WEIGHT		
APPROXIMATE	273#	(124 kg)

Summary Specifications: Models EST/EST-EXT

The Energy Mizer model EST low temperature, chemical sanitizing commercial dishwasher meets UL Electrical and ETL Sanitation (NSF Standard 3) standards WITHOUT the use of BOOSTER or TANK HEATERS. Model EST is constructed entirely of stainless steel. Each unit automatically washes, rinses and sanitizes food service utensils in standard 20" x 20" racks. Unit comes with upper and lower stainless steel wash arms. **Note: This machine does not have built-in heaters, therefore produces no steam.**

Available Models

- EST-AH Straight
  (17" Maximum clearance height for dishes)
- EST-C Corner
  (17" Maximum clearance height for dishes)
- EST-AH-EXT (Straight Extended Height)
  (20-1/2" Maximum clearance height for dishes)
- EST-C-EXT (Corner Extended Height)
  (20-1/2" Maximum clearance height for dishes)

Energy MIZER®

LISTED COMMERCIAL DISHWASHER 864T   LISTED COMMERCIAL DISHWASHER 864T   ENERGY STAR   ENERGY STAR PARTNER

CMA Dishmachines 12700 Knott Street, Garden Grove CA 92841• 800-854-6417 • 714-898-8781 • Fax: 714-895-2141 • www.cmadishmachines.com

CMA reserves the right to modify specifications or discontinue models without prior notification.

Printed in the U.S.A.

Appendix B: Appliance Specifications

CMA DISHMACHINES

Model EST 3-Door Ventless Door-Type Machine:
The Ventless process eliminates the installation cost of a hood/fan, annual operational cost of the hood/fan, and hood ventilation system cost. Water entering the booster heater has been pre-heated, reducing the energy cost to bring booster temperature to required 120 degrees, potentially saving THOUSANDS of $ in operation costs. NO VENT HOOD REQUIRED: Saves THOUSANDS of $ on installation.

NEW

CMA LOW TEMP-VENTLESS EST ENERGY SAVER

Chemical Sanitizing Single Rack Dishwasher

Features:

- **Energy Star® Qualified.**
- The HR System (Waste Air Heat Recovery) removes heat and water vapor that normally would be released when opening the dishmachine doors, utilizing that energy to preheat the incoming water; this saves energy while creating a safer and more comfortable environment.
- High tech condensation method converts the vapor to water, which evacuates the wash chamber at the end of the cycle.
- Three-door system for straight-thru or corner applications.
- Built-in "booster heater" assures proper wash and rinse temperatures (does not "tax" facilities' hot water supply).
- Auto Start System.
- Programmable (three-product) Dispensing System.
- Water Saving (1.09 gallons of water per rack of dishes).
- Automatic HR Condenser Cleaning System for daily coil wash-down.
- 30 racks per hour (90-second cycle and 30-second chamber purge).
- Top mounted controls.
- Door Safety Interlock System (DSI) assures that doors remain locked throughout the entire cycle, allowing the HR system to evacuate the vapor from the machine.

Available Options:

- Sanitizer Alarm
- Stainless steel dishtables and slant shelves

CMA Energy MIZER®
Registered Trademark

LISTED COMMERCIAL DISHWASHER 864T
ENERGY STAR

CMA Dishmachines 12700 Knott Street Garden Grove, CA 92841• 800-854-6417 • 714-898-8781 • Fax: 714-895-2141 • www.cmadishmachines.com

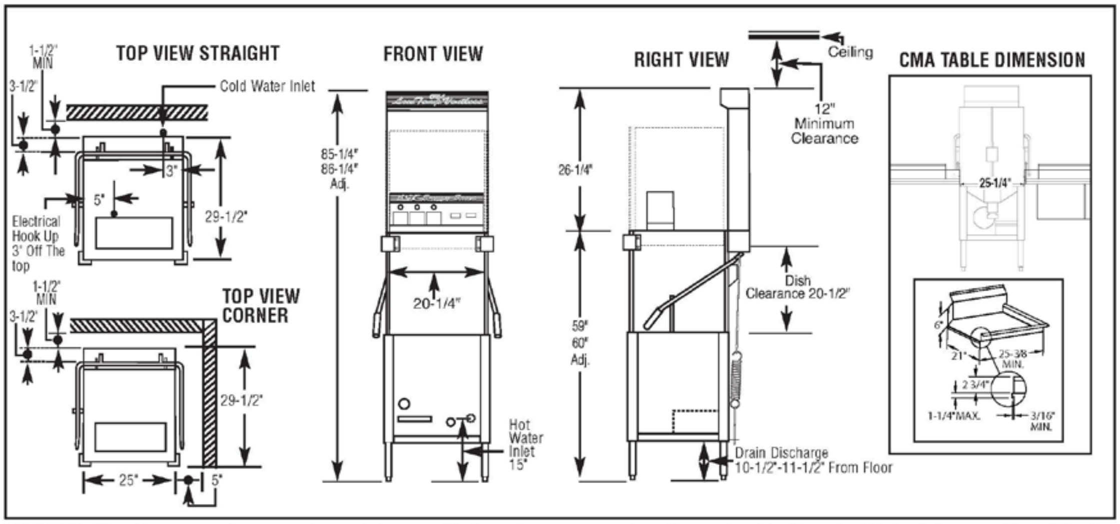
CMA reserves the right to modify specifications or discontinue models without prior notification.

Printed in the U.S.A.

CMA DISHMACHINES

CMA LOW TEMP-VENTLESS EST ENERGY SAVER

Chemical Sanitizing Single Rack Dishwasher



WARNING: Plumbing connections must be made by a qualified service company, who will comply with all required Federal, State, and Local Health, Plumbing and Safety codes.

Specifications:

MODEL LOW TEMP EST-VENTLESS	USA	METRIC
WATER CONSUMPTION		
PER RACK	1.09 GAL.	(4.12L)
PER HOUR	33 GPH	(125 L)
OPERATING CYCLE		
WASH TIME - SEC.	53	53
RINSE TIME - SEC.	30	30
DWELL - SEC.	7	7
VENT FAN	30	30
TOTAL CYCLE	120	120
OPERATING CAPACITY		
RACKS PER HOUR	30	30
WASH TANK CAPACITY	1.09 GAL.	(4.12 L)
PUMP CAPACITY	52 GPM	(197 LPM)
WATER REQUIREMENTS		
COLD WATER	40-65°F	(5°C-18°C)
HOT WATER	140°F	(60°C)
DRAIN CONNECTION	2"	(5.1cm)
HOT WATER INLET	1/2"	(1.3cm)
COLD WATER INLET	1/2"	(1.3cm)
OPERATING TEMPERATURE		
REQUIRED	120°F	(49°C)
RECOMMENDED	140°F	(60°C)

	USA	METRIC
FRAME DIMENSIONS		
DEPTH	29-1/2"	(79.2cm)
WIDTH	25"	(64cm)
HEIGHT	85-5/19"-86-5/16"	(216-217cm)
STANDARD TABLE HEIGHT	34"	(86cm)
EST MAXIMUM CLEARANCE HEIGHT FOR DISHES	20-1/2"	(52cm)
STANDARD DISHRACK	1	1
DIMENSIONS	19-3/4"X19-3/4"	(50X50cm)
WASH PUMP MOTOR HP	1	1
ELECTRICAL RATING	**VOLTS**	**AMPS**
DISHMACHINE	115 (1 PHASE)	16
BOOSTER HEATER	208/240 (3 PHASE)	25/29
	208/240 (1 PHASE)	43/50
SHIPPING WEIGHT		
APPROXIMATE	400#	(182 kg)

Summary Specifications: Model LOW TEMP EST-VENTLESS

The Energy Mizer Model EST Ventless low temperature, chemical sanitizing commercial dishwasher, meets UL Electrical and ETL Sanitation (NSF Standard 3) standards. Model EST Low Temp Ventless is constructed of stainless steel. Each unit automatically washes, rinses and sanitizes food service utensils in standard 20" x 20" racks. Unit comes with upper and lower stainless steel wash arms.

CMA Energy MIZER® Registered Trademark

LISTED COMMERCIAL DISHWASHER 884T

ENERGY STAR

CMA Dishmachines 12700 Knott Street, Garden Grove CA 92841• 800-854-6417 • 714-898-8781 • Fax: 714-895-2141 • www.cmadishmachines.com

CMA reserves the right to modify specifications or discontinue models without prior notification.

Printed in the U.S.A.

Addendum: Report Certification

EPA Organization ID: 1113443

This certifies that the undersigned has performed equipment testing according to the methodology outlined in the report described below, and verifies that the results recorded in that report were the actual results observed.

Report: CMA EST-AH / CMA EST-AH with Temp-Sure Heat Recovery Dishwashing Machine Expanded Test Report

Report #: 501311169-R0 Date published: December 2013

File name: 13_12_18_ 501311169_R0.PDF

Date sent for authorization: 12/18/2013

Tested by: (signature) Date signed: 12/18/13

Denis Livchak (print name) Research Engineer (title)

FNi Authorization: (signature) Date signed: 12/21/2013

David Zabrowski (print name) Director of Engineering (title)

PG&E Authorization: (signature) Date signed: 1/28/14

Charlene Spoor (print name) Senior Program Engineer (title)

1