Food Service
Technology Center

# CMA-180 / CMA-180-VL Dishwashing Machine Expanded Test Report

FSTC Report # 501311169-R0

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

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## Revision History

| Revision num. | Date | Description | Author(s) |
|---|---|---|---|
| 0 | January 2013 | Initial release | Rich Swierczyna / Denis Livchak |

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# 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 external 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, 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 hooded standard and ventless heat recovery door-type high temp dishwashing machines.


*Figure 1: CMA-180-VL Ventless Dishwashing Machine*

The CMA-180 is a door-type high temp electric dishwashing machine with an internal booster heater. A heat recovery version of this machine: CMA-180-VL (Figure 1) utilizes a blower motor that condenses the wash cycle vapor and forces it through a heat exchanger to preheat the incoming cold water supply. To determine dishwashing machine performance, FSTC engineers used 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 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 ener-

[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.

gy rate and production capacity was determined by washing racks of ten plates in succession while maintaining the required minimum wash tank temperature. The CMA-180 dishwashing machine achieved a washing energy rate of 361 wh/rack while washing 19.7 racks per hour with incoming hot water; the idle energy rate was 0.68 kW. The CMA-180-VL heat recovery dishwashing machine achieved a washing energy rate of 475 wh/rack while washing 15.8 racks per hour with incoming cold water; with the same idle energy rate.

Dishwashing machine heat gain to space is characterized by latent and sensible heat loading. The total convective heat gain to space for the CMA-180 standard unit was measured as 21.2 kBtu/h, which included a 6.0 kBtu/h sensible load and 15.2 kBtu/h latent load. The total heat gain to space for the CMA-180-VL heat recovery unit was measured as 13.0 kBtu/h, which included a 4.8 kBtu/h sensible load and 8.2 kBtu/h latent load. A summary of the test results is presented in Table 1.

*Table 1: Summary of CMA-180 Rack Dishwashing Machine Performance and Heat Loading*

| Appliance | CMA-180 | CMA-180-VL |
|---|---|---|
| Rated Input (kW) | 17.6 | 18.0 |
| Measured Maximum Energy Rate (kW) | 16.8 | 18.2 |
| Fill and Preheat Time (min) | 8.00 | 8.00 |
| Preheat Energy Consumption (kWh) | 1.28 | 1.28 |
| Idle Energy Rate (kW) | 0.68 | 0.68 |
| Washing Energy Rate (kW) | 5.43 | 5.47 |
| Washing Energy Rate (Wh/rack) | 361 | 475 |
| Washing Water Consumption (gal/rack) | 0.82 | 0.94 |
| Production Capacity (racks/hr) | 19.7 | 15.8 |
| Total Convective Heat Gain to Space (kBtu/h) | 21.2 | 13.0 |
| Sensible Heat Load (kBtu/h) | 6.0 | 4.8 |
| Latent Heat Load (kBtu/h) | 15.2 | 8.2 |

# Introduction

## Background

High temp 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. Dishwashing machine contribution to the total restaurant energy consumption is significant, often requiring external water heater energy to preheat large volumes of water and bring it up to sanitizing temperature using a built in electric booster heater. Ventilation has been a major issue with dishwashing machines usually 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. The cost of installing a ventilation system in a new location or retrofitting an existing location to the specified exhaust flow rate can be very costly. 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, reducing the water heating load of the restaurant. These appliances are also a significant sensible and latent heat source, having a huge impact on the cooling load of a restaurant as well as the thermal comfort of the restaurant employees.

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-180 door-type dishwashing machine 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 manufacturers' 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 140F water temperature to minimal operational wash tank 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-180 is an electric, high temp, door-type dishwashing machine with a rated input of 17.6 kW and a wash tank capacity of 8 gallons. The dishwashing machine features a built in booster heater rated at 12 kW and an electric resistance heating element inside the wash tank. The pump motor circulates the water during the wash cycle through two rotating nozzle arms located above and below the dish rack (Figure 2). There is a panel above the wash chamber with two gauges indicating the temperature of the wash tank and the rinse tank as well as a separate gauge indicating the rinse water pressure. 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-180-VL is a ventless heat recovery version of the CMA-180 dishwashing machine that features a heat exchanger to transfer heat generated by the wash cycle steam to the incoming cold water. 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-180-VL machine has a cold and a hot water connection, whereas the CMA-180 machine has a hot water connection only. For the heat recovery machine, the hot water connection is used to initially fill the wash tank with hot water only. The incoming cold water is used for the rinse cycle; it is first preheated by the condensing heat ex-

*Figure 2: CMA-180 Washing Cavity: Lower Wash and Rinse Arms*

changer and later by the internal booster heater to achieve rinse temperatures. 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 to the kitchen space as compared to a standard dishwasher.

*Table 2: CMA-180 Appliance Specifications*

| Appliance | Door-type High Temp Dishwashing Machine | |
|---|---|---|
| Manufacturer | CMA | |
| Model | 180 | 180-VL |
| Serial Number | 207337 | 206702 |
| Generic Appliance Type | Door-type Dishwashing Machine | |
| Total Rated Input | 17.6 kW | 18.0 kW |
| Booster Input | 12.0 kW | 12.0 kW |
| NSF Rated Rinse Water Consumption | 0.82 gal/rack | 0.96 gal/rack |
| Specified Wash Tank Volume | 8 gal | |
| Operating Voltage | 208 V | |
| Minimum Rated Wash Temperature | 155 F | |
| Minimum Rinse Temperature | 180 F | |
| Controls | On/Off; Autofill; Analog temperature gauges with automatic thermostatic tank heater elements | |
| Construction | Stainless steel | |
| Washing Cavity Dimensions (W x D x H) | 20" x 20" x 17.5" | |
| External Dimensions (W x D x H) | 25.5" x 25" x 73.5" | 25.5" x 25" 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 ambient air temperature of 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.


*Figure 3: CMA-180 Standard Dishwashing Machine with Installed under the 5 ft hood*

The CMA-180 dishwashing machine was 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.

*Table 3: Testing Equipment Inventory*

| Equipment Type (ID) | Manufacturer | Model | Measurement Range | Resolution | Calibration Date | Next Calibration Date |
|---|---|---|---|---|---|---|
| Dishwashing Machine electric meter (ALB 201) | Electro Industries | Shark 200 | 0.1 A – 75 A | 7.5 Wh | 11/13/12 | 11/13/13 |
| Booster Heater Electric Meter (ALC 309) | Continental Control Systems | WNB-3D-240-P | 0 A – 50 A | 0.05 Wh | 12/13/12 | 12/13/13 |
| Water Meter (SN: 10062935) | Omega | FTB4705 | 0 – 13 GPM | 545 pulses / gal. | (Verified Internally) 10/30/12 | NA |

Submerged Type K thermocouples were used to measure the incoming water supply, wash tank and rinse water temperatures on both dishwashing machines. Total electric energy was measured using a three-phase current transducer meter for the dishwashing machine. Additionally, a portable three-phase current transducer was mounted inside the dishwasher to separately monitor the energy consumption of the integrated booster heater. 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. The transducers and thermocouple probes were connected to a computerized data acquisition unit that recorded data every five seconds.

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, tree 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 heating elements are fully energized in the booster heater and the tank heater (such as during the rinse cycle). Prior to testing, the energy input rate was determined by measuring the energy consumed from the time the booster heater first began operating until the elements first cycled off. This procedure ensured that the dishwashing machine was operating within its specified parameters. The measured energy input rate of the dishwashing machine was 17.1 kW for the standard CMA-180 version and 18.2 kW for the CMA-180-VL heat recovery machine which included the heat exchanger fan energy. This energy consumption was within 3% from the nameplate rating. The water consumption of a dishwashing machine for a single rack washed is tested by NSF and listed on the manufacturer's nameplate. The internal water pressure regulator can be adjusted based on the potable water pressure to achieve the NSF water consumption rate. The water pressure during the rinse cycle was adjusted to 15 psi (Figure 4) to achieve a NSF rated water consumption of 0.82 gallons per rack for the

*Figure 4: CMA-180 Rinse Cycle Pressure*

CMA-180 machine. This water consumption was within 1% from the nameplate rating. The CMA-180-VL machine was tested at 24 psi rinse pressure to achieve 0.94 gallons per rack, which is within 2% of the 0.96 gallon per rack nameplate rating. Table 4 summarizes the results from the input test.

## Preheat and Idle Tests

These tests show how the dishwashing machine uses energy when it is not washing dishes, but ready to wash. The preheat test was conducted at the beginning of a test day after the dishwashing machine was stabilized at room temperature overnight with 140°F water at the inlet of the machine. The preheat test also includes the time it takes for the wash tank to fill with water, and the tank heater elements do not turn on until the elements are fully submerged. The preheat test recorded the time and energy required for the machine to reach minimum wash tank temperature of 155°F rated on the nameplate and also until the tank elements cycle off. The tank temperature was monitored next to the factory thermocouple located approximately one inch from the bottom (Figure 5).

*Figure 5: CMA-180 Tank Thermocouple location relative to factory temperature probe*

First, the dishwasher tank's thermostat was adjusted (Figures 6 and 7) so that the machine was able to maintain a minimum tank temperature of 155°F after washing three consecutive room temperature racks of dishes filled with 10 plates each. Data recording began when the dishwashing machine was first turned on, any time delay before the powering of the elements was included in the test. The tank was filled with 5.3 gallons of 140°F hot water over a period of 1 minute. During the preheat test, the dishwashing machine reached the minimum tank temperature of 155°F in 3.75 minutes while consuming 818 Wh of electrical energy. The CMA-180 machine took 8.00 minutes and 1,230 Wh of tank heater and booster electrical energy from the beginning of the fill to reach a set tank temperature of 186°F when the tank heater elements turned off. It took 4 minutes for the booster heater to preheat consuming 587 Wh. The preheat temperature and energy profile can be seen in Figure 8. Since both machines have the same booster and tank heaters, the preheat energy and time is the same for both machines when the tank thermostat is set for the same temperature setpoint. Idle energy rate represents the energy required to maintain the manufacturer's set point temperature, which is equivalent to the appliance's standby losses. After the dishwashing machine was preheated, it was allowed to stabilize for at least one hour. Time and energy consumption were monitored for an additional three-hour period while maintaining an operational average temperature of 181°F inside the wash tank. The idle wash tank temperature profile is shown in Figure 9. The idle energy rate including the booster heater for both CMA-180 and CMA-180-VL machines while maintaining a ready-to-wash state was 680 W with 569 W going to the tank heater and 111 W going to the booster. Preheat and idle test results are shown in Table 4.

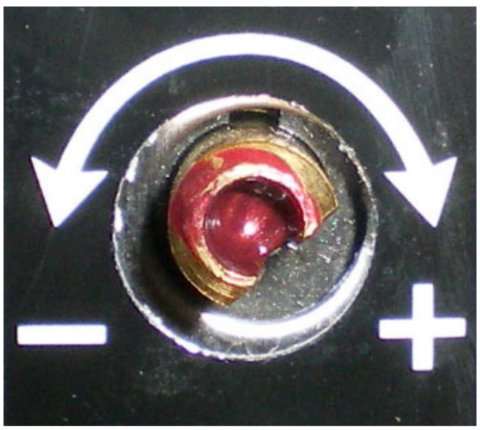


*Figure 6: CMA-180 Adjusted Thermostat*


*Figure 7: CMA-180-VL Adjusted Thermostat*

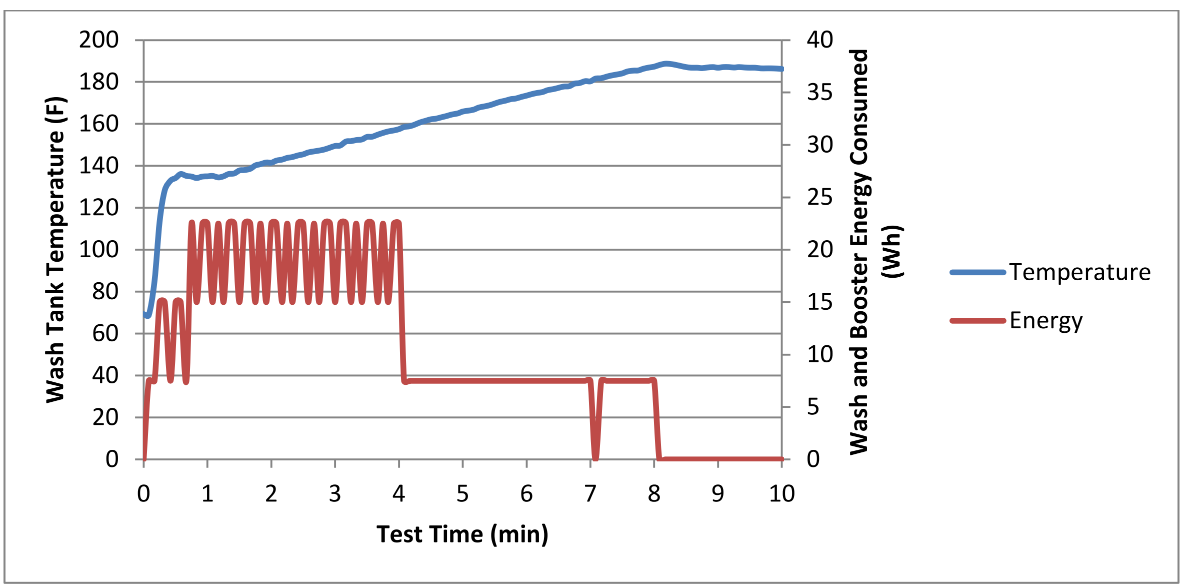


*Figure 8: Preheat: Tank Temperature and Energy Profile for the CMA-180 Door-type Dishwashing Machine*

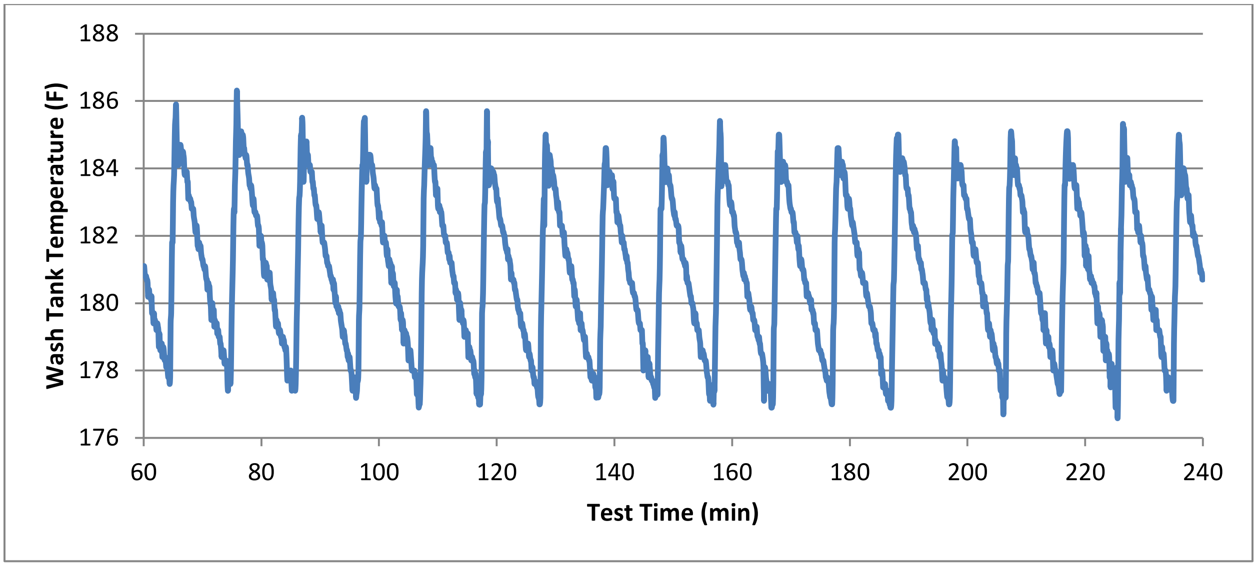


*Figure 9: Idle Tank Temperature Profile for the CMA-180 Door-type Dishwashing Machine*

*Table 4: Input, Preheat, and Idle Test Results for the CMA-180 Door-type Dishwashing Machine*

| Appliance | CMA-180 | CMA-180-VL |
|---|---|---|
| Rated Energy Input Rate (kW) | 17.60 | 18.00 |
| Measured Energy Input Rate (kW) | 17.07 | 18.21 |
| Percentage Difference (%) | 3.0 | 1.2 |
| Preheat Duration (min) | 8.00 | |
| Preheat Electric Energy Consumption (Wh) | 1,230 | |
| Preheat Temperature at location (°F) | 186 | |
| Tank Heater Electric Idle Energy Rate (kW) | 0.57 | |
| Booster Heater Electric Idle Energy Rate (kW) | 0.11 | |
| Total Electric Idle Energy Rate (kW) | 0.68 | |
| Average Idle Temperature at location (°F) | 181 | |

## 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 dishwasher was stabilized by an empty rack, and then was allowed to recover until the elements cycled off at 184°F. The washing test consisted of washing three sets of racks loaded with 10 dishes in rapid succession and allowing the wash tank elements to cycle off. 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 as quickly as possible. Every third rack of plates was left in the machine during the recovery period. A total of 6 sets of 3 racks were washed and the first set was discarded for stabilization resulting in 15 racks of dishes used for the washing test. The tank temperature was maintained above 155°F throughout the entire test. Figure 10 shows the wash tank temperature profile during the entire test.

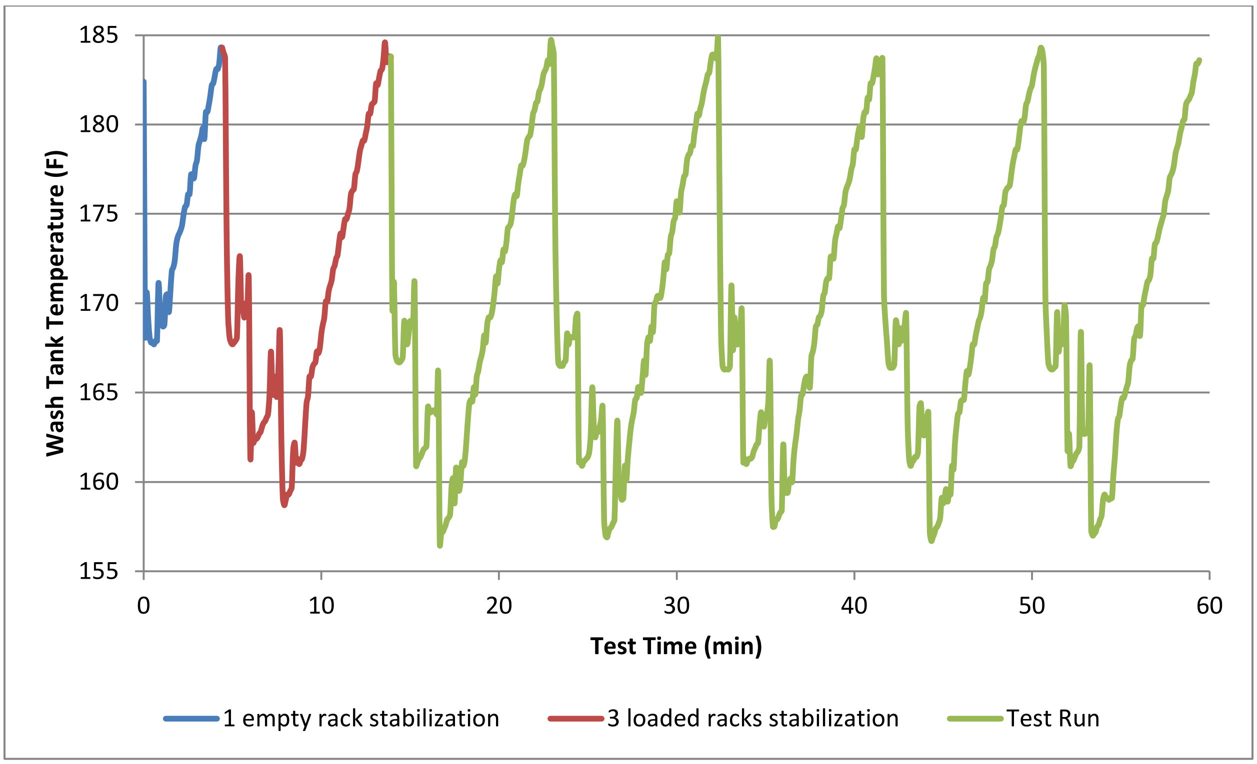


*Figure 10: CMA-180 Dishwashing Machine Wash Tank Temperature Test Profile*

Total dishwasher energy, booster heater energy and water consumption was recorded for each test run. The CMA-180 standard dishwashing machine demonstrated an average washing energy rate of 5.42 kW throughout the entire test. The production capacity for the dishwasher was 19.7 racks per hour. The CMA-180-VL heat recovery dishwasher energy included the heat recovery fan motor which turned on for 29 seconds after the rinse cycle. Both dishwashing machines recovered to 184°F before the elements cycled off in order to maintain the tank temperature above 155° throughout the entire test. The CMA-180-VL heat recovery dishwashing machine had a production capacity of 15.8 racks per hour operating at an average wash energy rate of 7.12 kW. CMA-180 used 276 wh of tank heating and pump energy and 86 wh of booster energy per rack washed using 139°F incoming water. CMA-180-VL used 347 wh of tank heating and pump energy and 128 wh of booster energy per rack washed using 71°F incoming water. Gas water heating energy was calculated for CMA-180 standard machine to bring up the water volume used for the washing test from 71°F to 139°F at 65% water heater efficiency which was 713 Btu/rack. Figure 11 shows the wash cycle times for each dish-washing machine and Table 5 summarizes the results from the dishwashing tests.

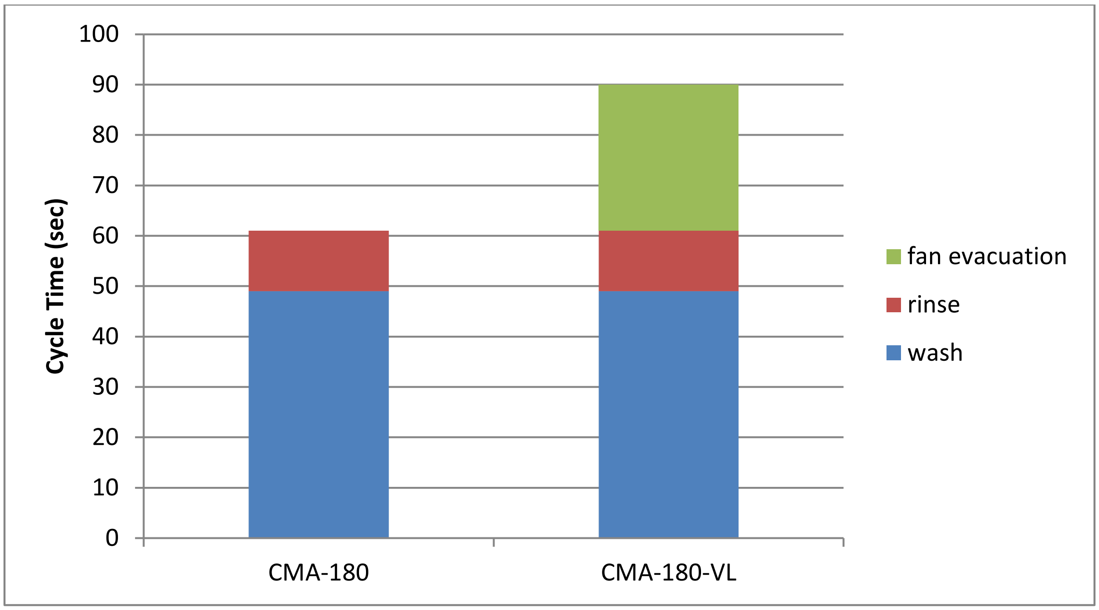


*Figure 11: CMA-180 Dishwashing Machine Cycle Duration*

*Table 5: CMA-180 Dishwashing Machine Washing Energy Rate and Production Capacity Test Results*

| Appliance | CMA-180 | CMA-180-VL |
|---|---|---|
| Total Washing Energy Rate (kW) | 5.42 | 7.12 |
| Total Washing Energy Rate (Wh/rack) | 361 | 475 |
| Booster Heater Energy Rate (Wh/rack) | 86 | 128 |
| Gas Water Heating Energy (Btu/rack) | 713 | 0 |
| Washing Water Consumption (gal/rack) | 0.82 | 0.94 |
| Average Supply Water Temperature (°F) | 139 | 71 |
| Average Rinse Water Temperature (°F) | 173 | 179 |
| Minimum Tank Temperature (°F) | 156 | 155 |
| Production Capacity (racks/hr) | 19.7 | 15.8 |

## Energy Cost Model

The test results can be used to estimate the annual energy consumption for the CMA-180 door type high temp dishwashing machine in a real-world operation. A simple cost model was developed to calculate the relationship between the various cost components (e.g., preheat, idle, water heating and washing costs) and the annual operating cost, 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 68°F temperature rise, specific weight of water is assumed to be 8.29 lb/gal at an average temperature of 105°F between 71°F and 139°F using Equation 3.

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

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

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

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

$$E_{\mathrm{gas\ water\ heating,\,daily}} = 8.29 * \mathrm{W} * \mathrm{GPR} * 68 / 0.65 \qquad \text{(Equation 3)}$$

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 per day, 364 days per year (excluding one holiday per year). The costs to air condition and/or ventilate the associated heat loads from the dishwashers will vary depending on the ventilation rate, climate zone and the amount of sensible and latent heat that is released into the space. The cost model is based on the minimum exhaust airflow rate specified in the International Mechanical Code of 100 cfm per linear foot of hood. For a 5-foot hood, the annual cost was calculated as part of a PG&E work paper as $1.55 per cfm for the state of California. The annual cost per cfm was calculated to be $0.73 per cfm based on fan power measurements. The cost model assumes conditioned makeup air. The calculated annual heating costs of conditioned air are $0.59 per cfm and the annual cooling costs are $0.23 per cfm based on annual weather data. Operating the hood at 500 cfm for CMA-180 will not eliminate the entire heat load generated the machine; the rest of the load would have to be offset by the restaurant's cooling system. Heat recovery may reduce the need for a ventilation hood if the remaining heat and moisture load is designed into the existing or into additional cooling capacity of the general HVAC. If the HVAC system is under-sized, the space will become hotter and more humid. Venting the unit correctly will guarantee heat and moisture removal.

Table 6 summarizes the annual energy consumption and associated energy cost for the dishwashing machine with different ventilation configurations.

*Table 6: CMA-180 Door-type Dishwasher Estimated Energy Consumption and Cost*

| Appliance | CMA-180 | CMA-180-VL |
|---|---|---|
| Preheat Energy (kWh/day) | 1.23 | 1.23 |
| Idle Energy (kWh/day) | 2.53 | 0.82 |
| Washing Energy (kWh/day) | 77.20 | 95.00 |
| Water Heating Energy (kBtu/day) | 143 | 0 |
| Annual Electric Energy (kWh/year) | 29,280 | 35,326 |
| Annual Gas Water Heating Energy (therms/year) | 521 | 0 |
| Annual Fan Energy Cost ($/year)[a] | 365 | 0 |
| Annual Makeup Air Heating and Cooling Costs ($/year)[b] | 410 | 0 |
| Annual Cost ($/year)[c] | 5,688 | 5,299 |

[a] Fan energy costs are based on a 500 cfm installed ventilation flow rate and an annual cost of $0.73 per cfm

[b] Air conditioning costs are based on the state of California weather data with $0.59/cfm annual heating and $0.23/cfm cooling costs

[c] Dishwashing energy costs are based on $0.15/kWh and $1.00/therm

## Heat Load Tests

These tests determined the heat load to the space from the both CMA-180 and CMA-180-VL dishwashing machines. 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 ventless 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 camera 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).

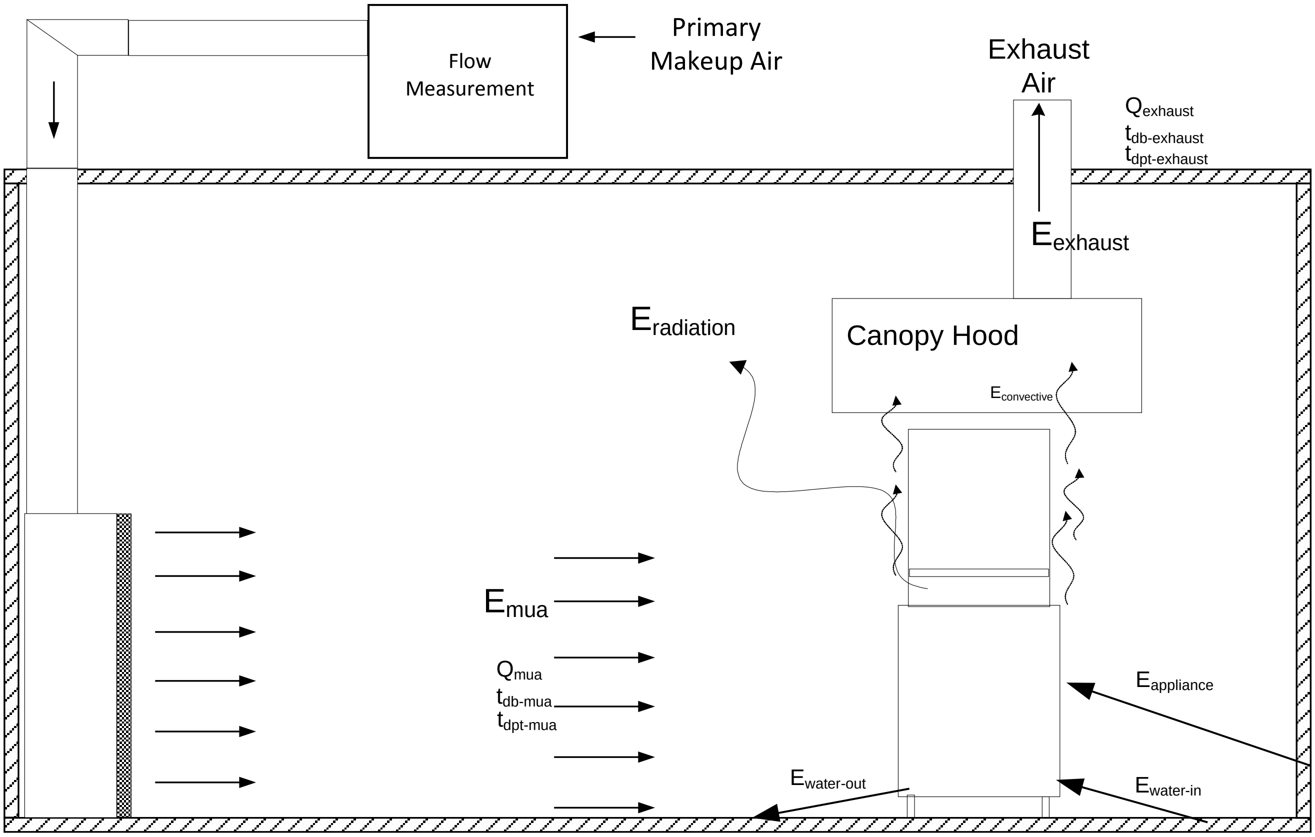


*Figure 12: Laboratory Energy Balance Diagram*

<u>Energy Balance</u>

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

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:

$q_{\text{space-sensible load}}$ is the convective sensible heat load to the space in Btu/h

$q_{\text{space-latent load}}$ 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 rise of ambient air to exhaust air conditions and the exhaust flow rate. The convective load was split into sensible and latent components by measuring humidity using a chilled mirror dew point transducer and temperatures using RTD measurement in the exhaust air stream.

The heat gain to space was measured for the CMA-180 standard dishwashing machine during idle conditions, as well as for the CMA-180-VL ventless heat recovery unit. The sensible convective load from both CMA-180 standard and CMA-180-VL heat recovery dishwashing machines during closed door idle conditions was 2,000 Btu/h and the radiant load was 300 Btu/h.

Heat load tests were also conducted during ASTM washing conditions. The dishwasher was stabilized by running five consecutive empty racks, and then was allowed to recover until the elements cycled off at 184°F. The washing test consisted of washing three sets of racks loaded with 10 dishes in rapid succession and allowing the wash tank elements to cycle off. 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 as quickly as possible. Every third rack of plates was left in the machine during the recovery period. A total of 6 sets of 3 racks were washed and the first set was discarded for stabilization resulting in 15 racks of dishes used for the washing test. The tank temperature was maintained above 155°F throughout the entire test. The convective heat load was separated into sensible and latent energy. Results of the tests are shown in Figure 13.

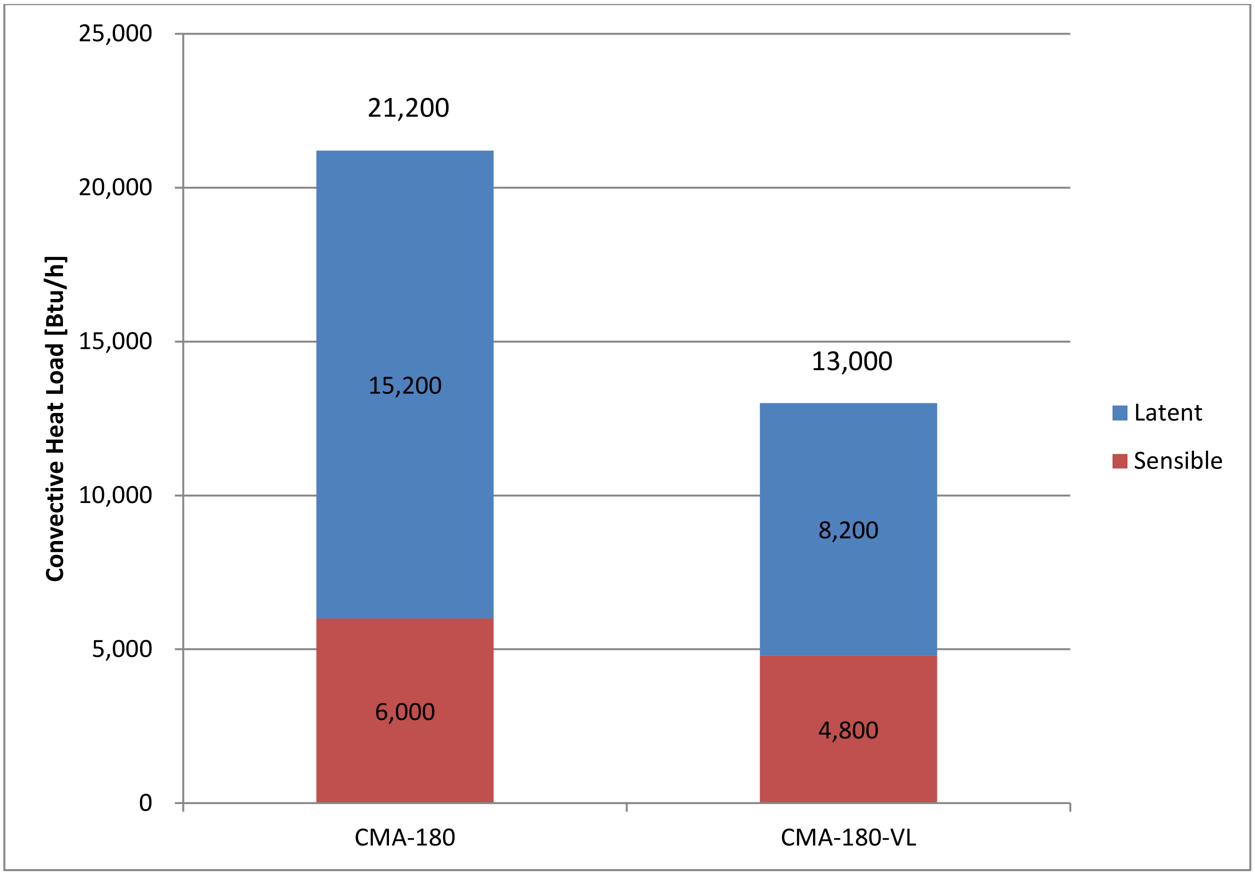


*Figure 13: Latent and Sensible Convective Heat Loads During ASTM Washing Conditions for the CMA-180 and CMA-180VL dishwashing machines*

Comparing the CMA-180 dish washing machine without heat recovery to the CMA-180-VL Condensing Unit, the total convective load was reduced by 8,200 Btu/h, or 39%, from 21,200 Btu/h to 13,000 Btu/h during ASTM testing. Without the condensing effect from the heat recovery unit, the latent load was 15,200 Btu/h from the standard high temperature sanitizing machine. The same machine with a Condensing Unit generated a latent load of 4,800 Btu/h. The condensing unit reduced the latent load by 7,000 Btu/h, or 46%. The sensible load was reduced by 1,200 Btu/h, from 6,000 Btu/h to 4,800 Btu/h during ASTM testing.

Heat load tests were also conducted during ASHRAE washing conditions as described in ASHRAE research project 1362 Revised Heat Gain and Capture and Containment Exhaust Rates from Typical Commercial Cooking Appliances. A standard dish rack with 10 plates was washed continuously for 20 dishwashing cycles without allowing plates to cool down. Each test cycle was 2 minutes for both CMA-180 and CMA-180-VL dishwashing machine. The convective heat load was separated into sensible and latent energy. Results of the tests are shown in Figure 14.

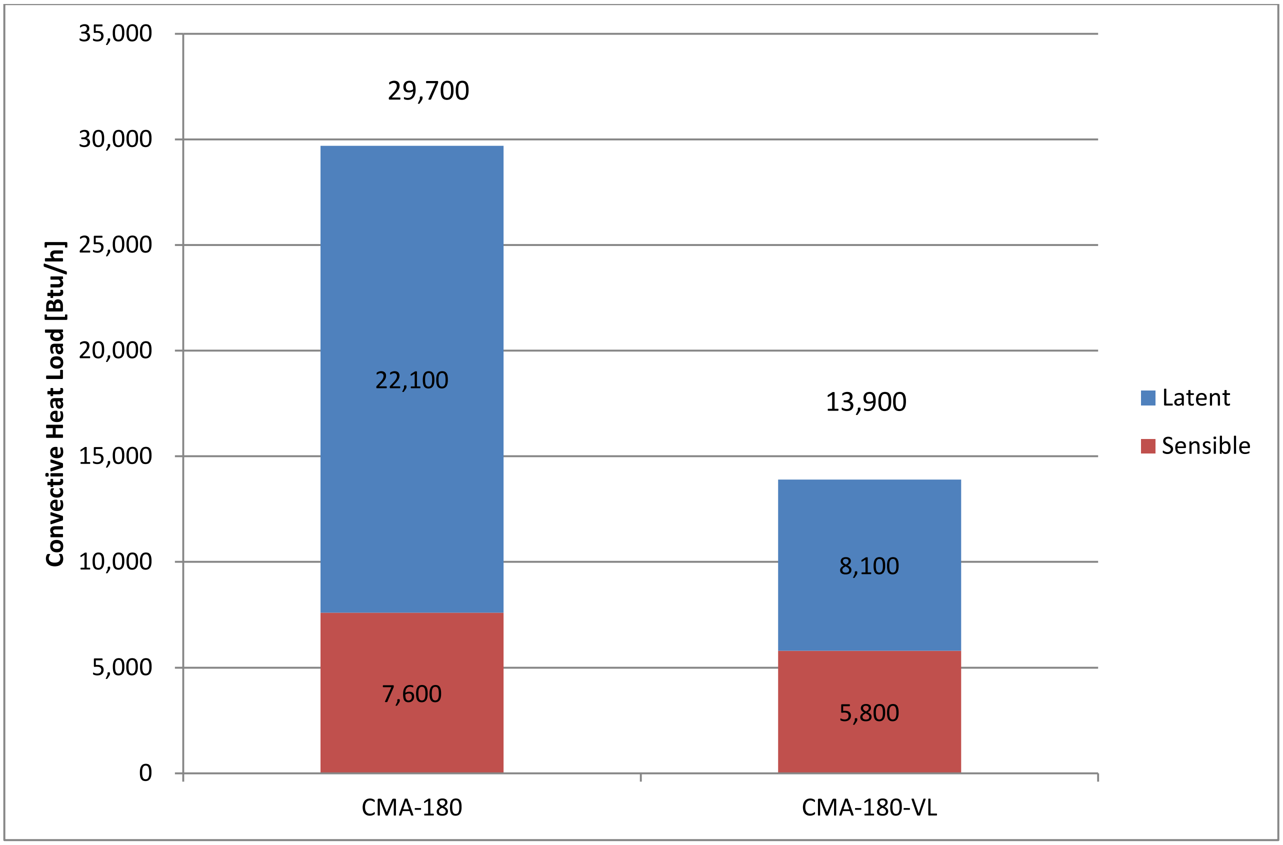


*Figure 14: Latent and Sensible Convective Heat Loads During ASHRAE Simulated Washing Conditions for the CMA-180 and CMA-180VL dishwashing machines*

Comparing the CMA-180 dish washing machine without the Heat Recovery to the CMA-180-VL Condensing Unit, the total convective load was reduced by 15,800 Btu/h, or 53%, from 29,700 Btu/h to 13,900 Btu/h during ASHRAE testing. Without the condensing effect from the condensing unit, the latent load was 22,100 Btu/h from the standard high temperature sanitizing machine. The same machine with a Condensing Unit generated a latent load of 8,100 Btu/h. The condensing unit reduced the latent load by 14,000 Btu/h, or 63%. During ASHRAE testing, the sensible load was reduced by 1,800 Btu/h.

During testing conditions, both CMA-180 and CMA-180-VL dishwashers were tested under a hood operating at 1700 cfm. In a restaurant environment the CMA-180 standard dishwashing machine is recommended to be installed under a Type II hood operating at the same flow rate as tested, capturing and removing 21,200 Btu/h of the machine's convective heat load. The CMA-180-VL ventless heat recovery machine could be installed without a hood, but the restaurant's ventilation system must be capable of absorbing the 13,000 Btu/h of the machine's convective heat load. Additionally, in all the dishwashing configurations, the restaurant's air conditioning system must be capable of offsetting the radiant heatgain of the dishwashing machine.

# 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**

## CMA-180

High Temperature
Straight or Corner Single
Rack Dishwasher


**STRAIGHT MODEL**


**CORNER MODEL**


**OPTIONAL 3 DOOR MODEL AVAILABLE FOR STRAIGHT AND CORNER OPERATION**

**FEATURES:**

- **Energy Star Qualified.**
- 60 racks / 240 covers per hour.
- Economical to operate. Uses only .96 gallons of water per cycle.
- Automatic soil purging system. Filters wash water and traps plate debris into an external tray. Tray can be easily removed for dumping contents.
- All stainless steel construction offers durable performance and years of trouble free operation.
- Built-in chemical resistant industrial 7kW heater is proven to be more durable than commercial style heaters.
- Unique spray arm system features upper and lower stainless steel wash arms with reinforced end caps. Specially designed pull-pins allow wash arms to be easily removed for cleaning.
- Top mounted control box is water tight and includes a rack counter, extended wash/delimer switch and easy to read temperature gauges.
- Auto start/stop makes operation safe and easy.
- Field convertible for a wide range of applications.
- Safety Temp feature assures 180°F sanitizing rinse every cycle.
- Single point electrical connection.
- Automatic tank fill.
- Interchangeable upper and lower arms.


Top mounted control box is water tight and includes a rack counter, extended wash/delimer switch and easy to read temperature gauges.

External scrap tray maintains clean wash water and prevents debris from clogging the drain.

Industrial wash tank and optional booster heaters are designed for years of trouble free service.

Unique pull-pin design allows wash arms to be easily removed for cleaning.

**Available Options:**

- Exhaust Fan Time Control
- Built-in 12kW booster heater
- CMA-180 Conversion Kit Corner to Straight
- CMA-180 Conversion Kit Straight to Corner
- Alternative electrical available for export
- Stainless steel dishtables
- Dual power supply connections
- Stainless steel scrap trap
- 3 doors open
- 2 minute cycle

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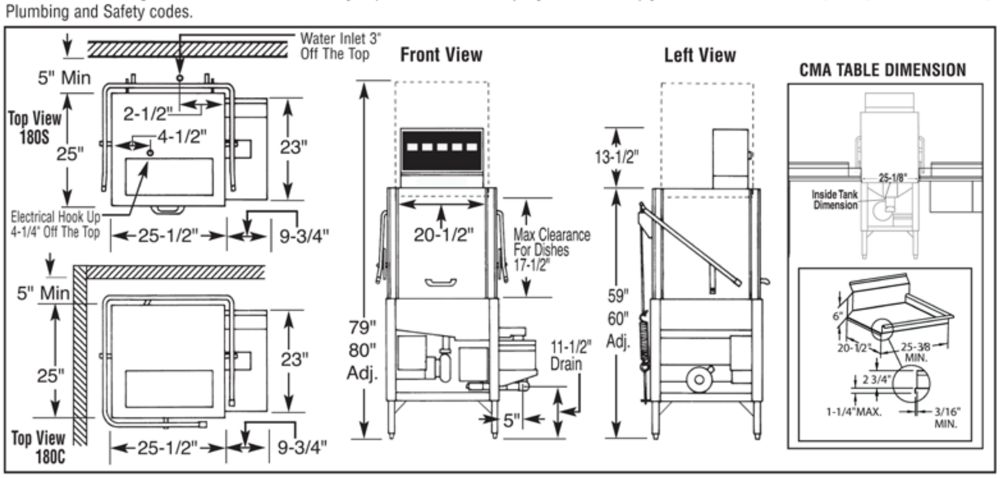
# Appendix B: Appliance Specifications

## CMA-180

High Temperature
Straight or Corner 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 CMA-180 | USA | METRIC |
|---|---|---|
| **WATER CONSUMPTION** | | |
| PER RACK | .96 GAL | (3.6 L) |
| PER HOUR | 52 GPH | (197 L) |
| **OPERATING CYCLE** | | |
| WASH TIME - SEC. | 49 | 49 |
| RINSE TIME - SEC. | 12 | 12 |
| TOTAL CYCLE | 61 | 61 |
| **OPERATING CAPACITY** | | |
| RACKS PER HOUR | 60 | 60 |
| **WASH TANK CAPACITY** | 8 GAL. | (30.3 L) |
| **PUMP CAPACITY** | 52 GPM | (197 LPM) |
| **WATER REQUIREMENTS** | | |
| WITHOUT BOOSTER HEATER | 180°F | (82°C) |
| WITH BOOSTER HEATER | 140°F | (60°C) |
| WATER INLET | 3/4" | (1.9cm) |
| DRAIN CONNECTION | 2" | (5.1cm) |
| RINSE PRESSURE SET | 20 ± 5psi | (1.41 kg/cm²) |
| **OPERATING TEMPERATURE** | | |
| WASH-°F (MIN) | 155°F-160°F | (68°C-71°C) |
| RINSE-°F (MIN) | 180°F-195°F | (82°C-90°C) |

| | | USA | METRIC |
|---|---|---|---|
| **WASH PUMP MOTOR HP** | | 1 | 1 |
| **DIMENSIONS** | | | |
| DEPTH | | 25" | (63.5cm) |
| WIDTH (OUTSIDE DIMENSION) | | 25 -1/2" | (65cm) |
| HEIGHT | | 59"-60" | (150-152cm) |
| STANDARD TABLE HEIGHT | | 34" | (86.3cm) |
| MAX CLEARANCE FOR DISHES | | 17-1/2" | (44cm) |
| DRAIN CONNECTION (OFF FLOOR) | | 11-1/2"-12-1/2" | (29-32cm) |
| **STANDARD DISHRACK** | | 1 | 1 |
| DIMENSIONS | | 19-3/4" X 19-3/4" | (50X50cm) |
| **ELECTRICAL RATING** | **VOLTS** | **PHASE** | **AMPS** |
| WITHOUT BOOSTER | 208 | 1 | 36 |
| | 240 | 1 | 38 |
| | 208 | 3 | 24 |
| | 240 | 3 | 26 |
| | 480 | 3 | 10 |
| WITH BOOSTER | 208 | 1 | 78 |
| | 240 | 1 | 88 |
| | 208 | 3 | 49 |
| | 240 | 3 | 55 |
| | 480 | 3 | 25 |
| **APPROXIMATE SHIPPING WEIGHT** | | | |
| WITHOUT BOOSTER | | 338# | (151kg) |
| WITH BOOSTER | | 351# | (170kg) |

**Summary Specifications: Model CMA-180**

The model CMA-180 single tank, high temperature dishwasher is designed for years of trouble free service, producing sparkling results while conserving energy, water and chemicals. This machine is available with an optional "built in" booster heater, assuring a continuous supply of 180°F hot water, and is easily field convertible for either corner or straight installation. Unique soil purging system filters wash water and plate debris into an external tray. The CMA-180 is NSF, UL, CUL and CE approved. Constructed entirely of stainless steel.

**Available Models**

- CMA-180S Straight
- CMA-180SB Straight with booster
- CMA-180C Corner
- CMA-180CB Corner with booster

ENERGY STAR
ENERGY STAR PARTNER

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# Appendix B: Appliance Specifications

## CMA-180-VL

High Temperature
3- Door Single Rack
Dishwasher


**The "Ventless" option is a Heat Recovery Condensation Removal System:**

**Captures and distributes normally exhausted heat from the wash/rinse tank, using this FREE energy to pre-heat cold water prior to feeding the booster heater. Water entering the booster heater has been pre-heated, reducing the energy cost to bring booster temperature to required 180 degrees, potentially saving THOUSANDS of $ in operational costs.**

**NO VENT HOOD REQUIRED: Saves THOUSANDS $ on installation.**

**Features:**

- **Replaces need for independent vent hood.**
- Final rinse valve receives cold water (45-70°F) that is processed through "heat recovery system", providing nearly cost free heating capabilities for water supplied to the booster heater, which reduces the recovery time for the booster heater.
- Heat recovery system captures water vapor from the wash & rinse cycle, and condenses it to heat the incoming cold water & evacuate the steam from the wash chamber.
- Door-actuated start.
- Safe-T-Temp feature assures 180°F sanitizing rinse every cycle.
- 12kW electrical booster heater.
- Booster-safety thermostat.
- 6kW wash tank heater.
- Low 0.96 US gallons of water usage per rack.
- Minimum 90-second cycle. (60 second wash/rinse & 30 second steam evacuation)
- 40 racks per hour (based on 90-second cycle).
- Fully automatic cycle for easy operation.
- Water level safety control.
- Maximum clearance for dishes is 17-1/2".
- All Stainless Steel construction.
- Wash tank screens, which filter recirculating wash water, prevent soil from entering spray arms.
- 3-door feature for straight or corner applications.
- Automatic heat exchange condenser wash-down feature.
- Rinse PRV supplied (Pressure Regulating Valve).
- Field convertible from three phase to single phase.
- Simple, rugged durability that you expect from CMA.

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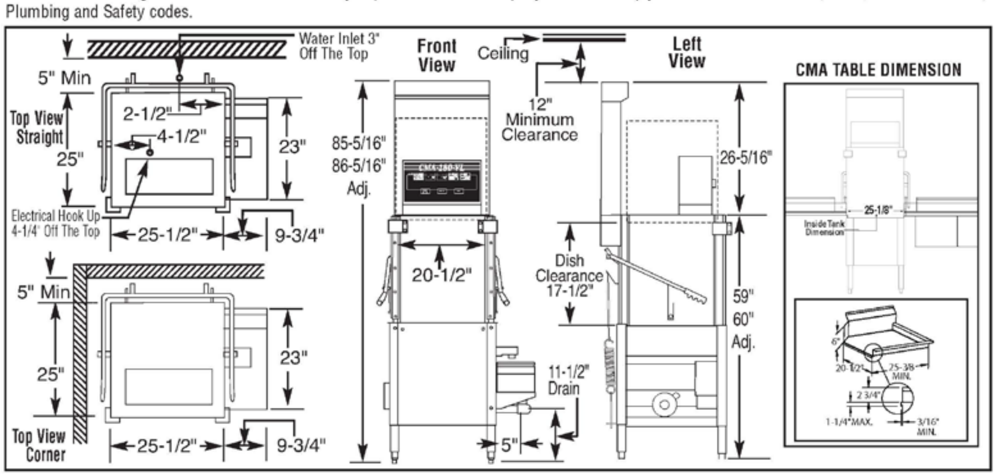
# Appendix B: Appliance Specifications

**CMA-180-VL**

High Temperature
3- Door 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 CMA-180-VL | USA | METRIC |
|---|---|---|
| **WATER CONSUMPTION** | | |
| PER RACK | .96 GAL | (3.6 L) |
| PER HOUR | 38 GPH | (197 L) |
| **OPERATING CYCLE** | | |
| WASH TIME - SEC. | 49 | 49 |
| RINSE TIME - SEC. | 12 | 12 |
| STEAM EVACUATION | 29 | 29 |
| TOTAL CYCLE | 90 | 90 |
| **OPERATING CAPACITY** | | |
| RACKS PER HOUR | 40 | 40 |
| **WASH TANK CAPACITY** | 8 GAL. | (30.3 L) |
| **PUMP CAPACITY** | 52 GPM | (197 LPM) |
| **WATER REQUIREMENTS** | | |
| RINSE | 45-70°F | (7.3°C-22°C) |
| FILL & CONDENSER | 140°F | (60°C) |
| DRAIN CONNECTION | 2" | (5.1cm) |
| RINSE PRESSURE SET | 20 ± 5psi | (1.41 kg/cm²) |
| **WATER REQUIREMENTS** | | |
| RINSE | 1/2" | (1.27cm) |
| CONDENDER | 1/2" | (1.27cm) |
| FILL | 3/4" | (1.9cm) |
| **OPERATING TEMPERATURE** | | |
| WASH-°F (MIN) | 155°F-160°F | (68°C-71°C) |
| RINSE-°F (MIN) | 180°F-195°F | (82°C-90°C) |

| | USA | METRIC |
|---|---|---|
| **WASH PUMP MOTOR HP** | 1 | 1 |
| **DIMENSIONS** | | |
| DEPTH | 25" | (63.5cm) |
| WIDTH (OUTSIDE DIMENSION) | 25 -1/2" | (65cm) |
| HEIGHT | 85-5/16"-86-5/16" | (216-217cm) |
| STANDARD TABLE HEIGHT | 34" | (86.3cm) |
| MAX CLEARANCE FOR DISHES | 17-1/2" | (44cm) |
| DRAIN CONNECTION (OFF FLOOR) | 11-1/2"-12-1/2" | (29-32cm) |
| **STANDARD DISHRACK** | 1 | 1 |
| DIMENSIONS | 19-3/4" X 19-3/4" | (50X50cm) |

| **ELECTRICAL RATING** | **VOLTS** | **PHASE** | **AMPS** |
|---|---|---|---|
| INCLUDES REQUIRED 12kW BOOSTER | 208 | 1 | 80 |
| | 240 | 1 | 90 |
| | 208 | 3 | 50 |
| | 240 | 3 | 56 |
| **APPROXIMATE SHIPPING WEIGHT** | | 400# | (182kg) |

**Summary Specifications: Model CMA-180-VL**

The model CMA-180-VL single tank, high temperature dishwasher is designed for years of trouble free service, producing sparkling results while conserving energy, water and chemicals. This machine is supplied with a built-in 12 kW booster heater required for "Ventless" feature to function. The CMA-180-VL comes standard with the 3-door feature for straight or corner applicarions. Unique soil purging system filters wash water and plate debris into an external tray. The CMA-180-VL is NSF, UL, CUL and CE approved. Constructed entirely of stainless steel.

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## Additional 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.

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Pacific Gas & Electric, 2012. Work Paper PGECOFST116 Commercial Kitchen Demand Ventilation Controls. San Francisco, CA.

# Food Service Technology Center

## 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-180 / CMA-180-VL Dishwashing Machine Appliance Test Report (S/N# 207337)

Report #: 501311169-R0 Date published: January 2013

File name: 13-01-23 CMA 180 Full Report.pdf

Date sent for authorization: 01/28/2013

Tested by: Denis Livchak (signature) Date signed: 1/24/13

Denis Livchak (print name) Research Engineer (title)

FNi Authorization: (signature) Date signed: 2/1/2013

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

PG&E Authorization: (signature) Date signed: 1/30/13

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