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Design and Testing of Microwave Safe Ceramic Ware

Standard:

ASTM C1607-12 Standard Test Method for Determination of "Microwave Safe for Reheating" for Ceramic Ware.

Introduction:

Since the emergence of the microwave oven in the 1980's, microwave ovens have been a common household item. Microwave ovens are used for defrosting, reheating, and cooking food. High-powered microwaves generated from a magnetron randomly bounce along the inside of the microwave, often passing through the food. This randomization and rotating turntable is crucial to ensuring that food is reheated or cooked evenly. Due to the high-powered waves, only certain materials are to be used in the microwave. Metals, for instance, are not to be inserted in a microwave due to the highly conductive nature of the material reflecting the microwaves back into the cavity. The reflected waves cause arcing and consequently, damage the microwave (US4591683A, 1986). This study highlights the design and testing methods used for determining the microwave safe rating often found on cookware.

Technical Terms:

The orange outline in figure 1 depicts the microwave oven cavity. The cavity includes the inside of the microwave, meaning the area where the microwaves are active.

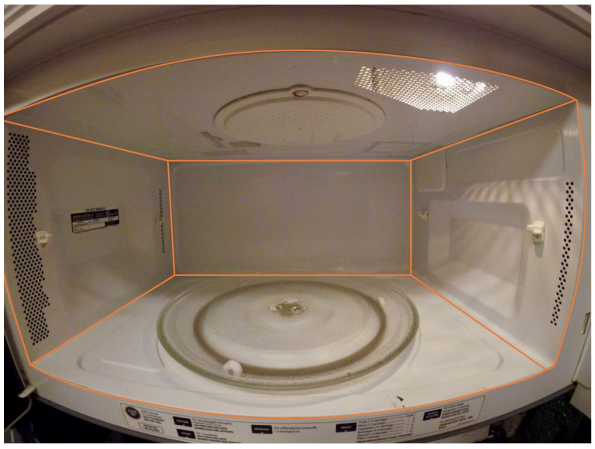


Fig. 1: Microwave Oven Cavity.

Applications:

The ceramic ware examined in this text is to be used in only consumer based microwave ovens, not commercial ones. This testing method only focuses on the defrosting and reheating of food, not cooking. Prior to completing this testing method, any ceramic products that are to be used in microwave ovens are to pass ASTM C554. It is explicitly stated the material to be used in this testing method is ceramic ware, not metallic or polymeric based cookware. In addition, any ceramic ware with a metallic trim or other features are to not be used.

Design:

As stated before, the ceramic ware used for this test needs to be non-metallic or polymeric based. This restriction limits the variety of material used when designing the cookware. Likewise, the artistry on the cookware is limited to only microwaveable (as well as food) safe material. Failure to consider these aspects of designing cookware would result in cookware that does not pass the standard presented in this text.

Since this test is only to be used for consumer microwave ovens, the design of the cookware is limited to a specific size and shape. As stated in the standard, the microwave oven cavity is to have a volume of 1.58 ft^3 with dimensions of 9 x 16 $\frac{7}{16}$ x 18 $\frac{1}{2}$ in. Although the dimensions represent a maximum size for the microwave oven's cavity, the designer must account for the diameter of the rotating table. The cookware must be small enough to fit comfortably on the rotating table. In addition, the designer must account for clearance when the turntable rotates the cookware. In figures 2 and 3, the cookware is able to rotate 360 degrees. Adversely, figures 4 and 5 demonstrate the the cookware being too large for the microwave and therefore, not being able to rotate the full 360 degrees.



Fig. 2: Properly Designed Cookware.



Fig. 3: Cookware Rotated 90◦



Fig. 4: Improperly Designed Cookware.



Fig. 5: Cookware Rotated 90◦

Testing:

Due to the standard regarding the testing of whether the selected cookware is microwaveable safe or not, this section will detail the apparatus, materials used, hazards, calibration method, procedure, and criteria.

Apparatus

As mentioned previously, the microwave oven should have a volume of 1.58 ft^3 with dimensions of 9 x 16 $\frac{7}{16}$ x 18 $\frac{1}{2}$ in. The microwave oven should have a power rating close to a mid-size consumer product to replicate slightly tougher conditions. The mid-size microwave oven should have a magnetron rated between 900 to 1300 watts. One can find the wattage of their microwave by looking on the inside wall.

Materials

The materials needed for this testing method include access to tap water, two plastic beakers (1 L and 500 ml), one 250 ml graduated cylinder, eye protection such as safety glasses or goggles, insulated and waterproof gloves or oven mitts, a permanent marker, a scale capable of reading 1200 ± 0.5 g, and boiling stones.

Hazards

The boiling stones should always be used when boiling the tap water. If distilled water is used instead of tap water, the distilled water is more likely to superheat and spontaneity erupt. This could be disastrous and caused significant burns and other injuries. Handling the material with oven mitts will greatly reduce the chances of injuries. Also, to reduce the chance of radiation leakage, one must stand at least 20 in. away from the microwave oven. Finally, those with pacemakers should not conduct this test. This is due to the microwaves potentially interfering and possibly permanently damaging the pulse generator.

Those conducting the test must inspect both the inside and outside of the microwave. The outside of the microwave must be examined for any damage to the door, hinges, or door seals. If there is damage, the microwave may leak radiation, which can be harmful. The inside of the microwave including the cavity, door, and door frame must be examined for any holes. Holes on the inside of the microwave are caused by electrical arcing.

Calibration

To guarantee the results from the testing method are correct for all those performing the test, the calibration is extremely vital to the success and validity of the test. The following steps ensure the microwave oven is producing consistent power levels. To begin the calibration, record the weight of the empty plastic beaker. Add 1.0 kg (1000.0 $\pm$ 0.05 g) of tap water to the plastic beaker then equilibrate the water to room temperature 73 $\pm$ 4 $\circ$ F (23 $\pm$ 2 $\circ$ C). Measure the water to $\pm$ 0.2 $\circ$ F ($\pm$ 0.1 $\circ$ C). Place the beaker filled with water in the center of microwave oven and run the microwave on the highest power rating for 2 minutes. After 2 minutes, remove the beaker using hand protection, stir the water for 10 seconds, then measure the temperature of the water while constantly stirring. In those 10 seconds, the maximum temperature should be recorded to $\pm$ 0.2 $\circ$ F ($\pm$ 0.1 $\circ$ C). It is important to note that a new sample should be used for every new measurement. The absorbed power of the microwave is found using equation 1. Table 1 can be used to determine each variable. The absorbed power rating should be required for each sample and the results should be compared to determine any decline in power level.

$$P = \frac{(K\ Cp\ m\ \Delta T)}{t} \qquad (1)$$

Table 1. Variable Details for Equation 1.

Variable	Description	Units
P	Power absorbed by the sample	Watts (joule/sec)
K	Conversion factor from thermochemical calories/second to watts	4.184 joule/cal
Cp	Heat capacity, specific heat, or thermal capacity of water	cal/g $\circ$ C
m	Mass of the water sample	grams
ΔT	Final temperature minus initial temperature	$\circ$ C
t	Time	sec

In addition to the power absorption calibration method, the cookware must also be conditioned. The cookware must be heated to 325 ◦ F (163 ◦ C) for one hour. After one hour, the cookware is removed then submerged in cold tap water and stored overnight. The cold water will travel into the piece which represents what will happen when the item is used.

Procedure

To be considered microwaveable safe, flatware must pass two tests. The first test represents only 1 minute of reheating small quantities of food. The second test imitates heating or defrosting large quantities for 5 minutes. A third test for cups is also detailed.

To begin the 1 minute test, a 500 mL beaker filled with 250 mL tap water at 60 ◦ F (16 ◦ C) is placed in the back left corner of the microwave oven. With a permanent marker, mark the flatware at 3 separate points that are 120 ◦ from each other. These marks should be close to the outer rim. On the backside of the flatware, mark a point in the center. The flatware must be at room temperature and the glass turntable must be below 100 ◦ F (38 ◦ C). Place the flatware on the glass turntable and in the center of the microwave oven and run the microwave for 1 minute on the highest power rating. After one minute, remove the flatware with hand protection and record the temperatures at the areas marked with the permanent marker. These measurements should be recorded within 15 seconds of removal. The initial three marks should be recorded first and the fourth recorded last. Scan the entire surface of the flatware and record the maximum temperature found. If this test is to be performed multiple times, replace the 500 mL beaker and 250 mL tap water before every test.

The second test method for larger quantities follows similar guidelines of those presented for the 1 minute test. A 1.0 L beaker is filled with 500 mL of tap water at 60 ◦ F (16 ◦ C). In the same manner as mentioned before, mark the flatware and check the temperature of the flatware and glass turntable. Place the flatware on the glass turntable (in the middle) and the 1.0 L beaker in the middle of the flatware. The 1.0 L beaker imitates food in this test. Run the microwave on the highest power setting for 5 minutes. Remove the flatware and beaker with hand protection and record the temperature in the marked spots within 15 seconds of removal.

Finally, the third test detailed in this section regards the testing for microwavable safe cups. The internal volume of the vessel must be measured, recorded, and filled only halfway with tap water. With a permanent marker, mark 3 separate points on the outer rim 120 ◦ from each other. Mark the top and bottom of the surfaces where the handle meets the outside surface and the center of the outer surface of the handle. Place the cup in the center of the microwave and run the microwave for 2 minutes on the highest power rating. Remove the cup and empty it. Within 25 seconds, record all temperatures at each point marked. Record the maximum temperature when continually moving the probe over the outside surface of the cup.

Criteria

Once all the results are collected and organized in a readable manner, the cookware must be evaluated. The physical appearance of the cookware must be examined for cracks, discoloration, or deformation. If these deformities are apparent, the cookware fails the test. The results for the 1 minute test must be 160 ◦ F (71 ◦ C) or less. The results for the 5 minute test must be 325 ◦ F (163 ◦ C) or less. The 2 minute test for cups must have handle temperatures of 140 ◦ F (60 ◦ C) or less and body results of 250 ◦ F (121 ◦ C) or less. If the cookware passes the criteria outlined above, the cookware is concerned microwavable safe.

Conclusion:

Common household cookware design often does not require a second thought. For most, the only knowledge that pertains to microwave ovens is taught from a young age and that is not to place metal in the microwave. Standard ASTM C1607 - 12 outlines multiple testing methods for determining whether cookware is microwavable safe or not. The standard highlights the hazards, apparatus requirements, a calibration method, multiple testing procedures, and the criteria the cookware needs to pass. A designer must not only consider food safety related standards, but also microwavable safe standards. The design considerations associated with these standards include the type of material used, the volume, and overall shape of the cookware. Although cookware is not considered a complex product, one must pay close attention to detail when designing and testing.

References:

The American Society of Mechanical Engineers, 2016, *Standard Test Method for Determination of "Microwave Safe for Reheating" for Ceramicware* (ASTM C1607 - 12).

Eke, K. I. (1986). *United States Patent No. US459183A.* Washington, DC: U.S. Patent and Trademark Office.