Designation: F874 – 98 (Reapproved 2014)

Standard Test Method for Temperature Measurement and Profiling for Microwave Susceptors[1]

This standard is issued under the fixed designation F874; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This is a test method for measuring surface temperatures attained by microwave interactive packaging and cooking aids (that is, susceptors). It is useful for measuring susceptor/food interface temperatures during microwave preparation of foods with susceptor-based packaging, heating pads, and crisping sleeves, etc. It may also be used to measure the temperature of a susceptor exposed to extractives testing or in a liquid extraction cell to be used for nonvolatile extractives testing. The latter procedures are performed to establish test conditions for conducting extraction and migration studies using temperature versus time profiles approximating those for actual microwave preparation of the product.

1.1.1 Several of the steps of this test method are taken directly from Test Method F1308 which gives extraction testing procedures for susceptors.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1308 Test Method for Quantitating Volatile Extractables in Microwave Susceptors Used for Food Products

F1317 Test Method for Calibration of Microwave Ovens

F1349 Test Method for Nonvolatile Ultraviolet (UV) Absorbing Extractables from Microwave Susceptors

F1500 Test Method for Quantitating Non-UV-Absorbing Nonvolatile Extractables from Microwave Susceptors Utilizing Solvents as Food Simulants

3. Apparatus

3.1 *Microwave Oven,* no turntable, unmodified except for small holes to allow for probe lead access to the oven cavity. The oven should be calibrated in accordance with Test Method F1317.

3.2 *Fluoroptic Thermometry System* .

3.3 *Vials,* headspace, 20 mL.

3.4 *Septa,* polytetrafluorethylene (PTFE) polymer faced silicone rubber.

3.5 *Vial Crimp Caps.*

3.6 *Microwave Nonvolatile Extraction Cell*—This cell must be constructed of PTFE-fluorocarbon polymer. Additional details on this cell may be found in Test Method F1349.

3.7 *Beakers,* 600 and 250 mL, or other sizes as appropriate.

3.8 *Aluminum Foil,* household roll.

3.9 *Adhesive Tape,* such as Kapton high-temperature tape, vinyl tape, silicone tape, etc.

3.10 *High-Vacuum Silicone Grease* .

3.11 *Syringe Needle,* 13 gage diameter.

3.12 *Corn Oil,* Miglyol 812 (a fractionated coconut oil), or synthetic fat simulant HB 307. See Test Method F1349 for details.

3.13 *Petri Dishes.*

3.14 *Fan,* tabletop.

3.15 *Blue Ice.*

3.16 *Vials,* for alternative profile method, 40-mL clear vials.

3.17 *Screw Caps.*

4. Procedure

4.1 *General:*

4.1.1 Start all tests with a cool microwave oven, that is, ambient temperature. Use a fan and blue ice to cool oven floor

[1] This test method is under the jurisdiction of ASTM Committee F02 on Flexible Barrier Packaging and is the direct responsibility of Subcommittee F02.15 on Chemical/Safety Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

or any other reliable method to suitably return the oven to ambient temperature between replicates.

4.1.2 Test three replicates per variable.

5. Measurement of Food/Susceptor Interface Temperature During Microwave Cooking

5.1 Place product in center of the microwave oven as a consumer would. Mark the position of first replicate on oven floor, and position subsequent replicates similarly.

5.2 Position probes at food susceptor interface in such a manner that good probe/susceptor contact is maintained during cooking, disturbing the food load as little as possible. The analyst may wish to position multiple probes on different regions of the susceptor, such as the center and edge, as the temperature attained at different locations may differ significantly.

5.2.1 If the nature of the product permits, the analyst may wish to determine whether probes positioned parallel to the susceptor surface, or abutted to the susceptor surface would result in better temperature measurement as evidenced by better reproducibility between replicate runs and less discontinuity, due to loss of contact, of temperature readings versus time.

5.3 For in-package measurements for products such as microwave popcorn, probe access into the package is achieved by drilling approximately 0.1-in. holes through the package. (See Fig. 1 for probe placement inside a popcorn bag.) It is also advisable to route the probes along the bottom of the package to avoid disruption of probe/susceptor contact as the bag expands during cooking. If it has been demonstrated that the outer bag surface and inner bag surface temperatures are equivalent, then taping the probes to the outer surface would be satisfactory.

5.4 For products prepared on a susceptor board, such as microwave pizza, the probe should be immobilized to the susceptor board in parallel contact by applying a suitable adhesive tape 0.5 in. behind the probe tip.

5.5 For products without free fat or oil at the food susceptor interface, it is advisable to apply high-vacuum silicone grease to the tip of the probe to assure good thermal contact with the susceptor.

5.6 Microwave at full power for the maximum directed cooking time of the product, recording the temperature of each probe, preferably at 5-s intervals, but at intervals not to exceed 15 s. It is suggested that readings be taken at 1-s intervals if possible, in order to generate a smoother curve. Calculate the average of the replicate runs at each recorded time for each probe position. Do not use data if discontinuities appear in plot (indicative of loss of susceptor/probe contact).

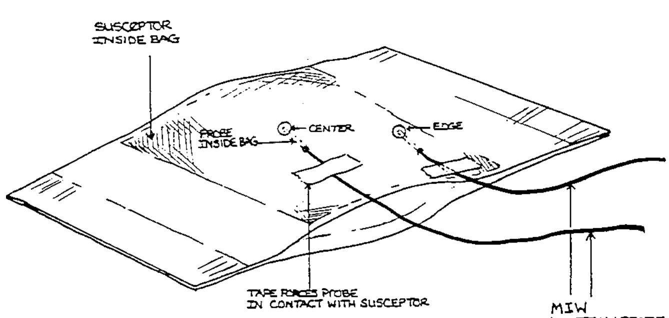

FIG. 1 Probe Configuration for Popcorn Bag Temperature Measurement

6. Temperature Profiling of Susceptors in Vials Used for Volatile Extractives Testing

6.1 First determine the temperature versus time profile for the product during microwave preparation in accordance with Section 5.

6.2 Cut a 10 by 65-mm (6.5 cm^2 or 1-in. ^{2}) portion from the susceptor sample to be tested. Insert carefully into vial, positioning the sample on the vial side, with the active side facing into the vial.

6.3 Using a 13-gage syringe needle, pierce a hole into a septum, place septum on vial and crimp.

6.4 Insert one temperature–sensing probe through the septum hole into the vial and manipulate it until it is in contact with the active face of the susceptor material.

6.5 Place vial on its side in the center of the microwave oven, marking the exact location on the oven floor for subsequent replicates. Place the cap of the vial towards the probe access port in the oven cavity, with susceptor active face up.

6.6 As an alternative to 6.2 through 6.5, multiple probes can be used for doing temperature profiling, using the following procedure. Cut a 10 by 65-mm portion from the susceptor sample to be tested. Using a razor blade, carefully cut an "X" in the center of the septum. Place the number of temperature-sensing probes to be used through the open hole in the screw cap and then through the "X" in the septum and attach them to the sample using the adhesive tape to maintain continuous contact. Place the sample, with probes attached, into the vial and secure the screw cap onto the vial. Place the vial on its side in the center of the microwave oven, marking the exact

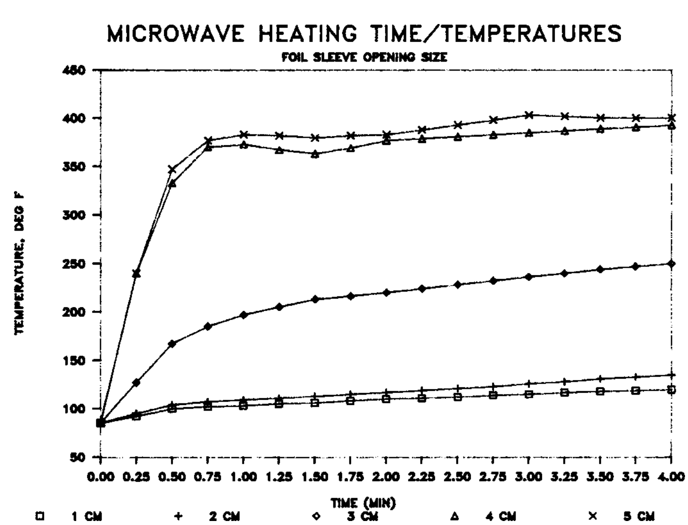

FIG. 2 Effect of Foil Sleeve Window Size (cm^2) on Temperature Attained by Frozen Fish Product Susceptor

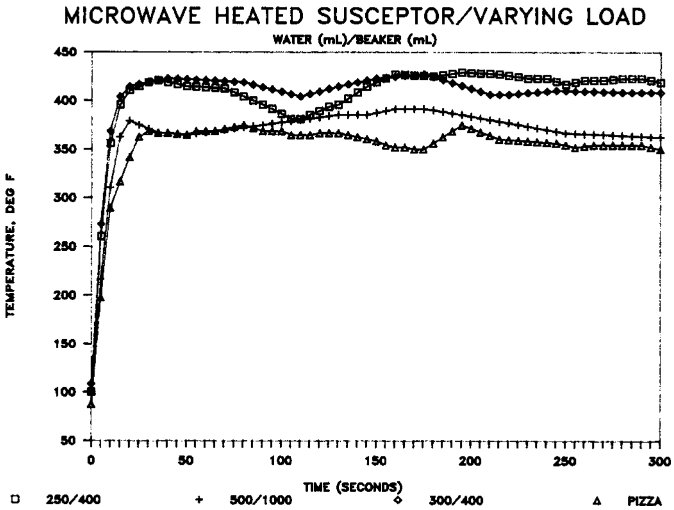

FIG. 3 Temperature Profiles for Microwave Pizza and Its Susceptor In Vial With Different Water Loads

location on the oven floor for subsequent replicates. Again, place the cap of the vial toward the probe access port in the oven cavity.

6.7 Before proceeding with replicate runs, one must first perform trial runs to determine the extent of water loading or vial shielding necessary to limit the microwave energy exposure of the susceptor to an amount which will result in a temperature that closely approximates, or is slightly higher than, that attained when used with actual product.

6.7.1 Adjustment of the water load can be achieved by varying the mass of water in one or more 600-mL beakers or by varying the beaker size to change the water surface area. For instance, one 600-mL beaker containing 500 mL of water is commonly used for microwave popcorn susceptors.

6.7.2 Use of a water load is recommended for products which do not contain large amounts of frozen water such as popcorn and pizza. For products containing large amounts of frozen water such as frozen fish, it will likely be necessary to shield the sample from overexposure to microwave energy by wrapping a foil sleeve with a cut-out window around the vial. F1349 by 3-cm window directed toward the in-feed port (the area where the microwaves are being fed into the oven) has been used successfully for volatile extractives studies for susceptors used for frozen fish products. Successful application of this technique may depend on position of magnetron in oven.

6.8 Microwave at full power for the time period used in 5.6, recording the probe temperature, preferably at 5-s intervals, but at intervals not to exceed 15 s. Again, the more frequent readings that can be obtained will give a smoother, more traceable curve. Calculate the average from the replicate runs at each recorded time.

6.9 Plot the average temperature as a function of time from 5.6 (using the data from the hottest recorded region of the susceptor) and 6.8.

6.10 Compare the plots. If the trace from the vial-enclosed sample closely approximates or is slightly higher than that for the product during microwave preparation, then the test conditions employed for the in-vial runs are acceptable for conducting volatile extractives testing for this susceptor application. If the trace is substantially higher or lower than that of the susceptor with product, then adjust the mass or surface area, or both, by changing container size of the water (using a fresh sample of room-temperature distilled water), or adjust the degree of vial shielding by altering the size of the window in the aluminum foil. Repeat 6.8 and 6.9.

7. Temperature Profiling of Susceptors in PTFE-Fluorocarbon Polymer Cells Used for Nonvolatile Extractives Testing

7.1 First, determine the temperature versus time profile for the product during microwave preparation in accordance with Section 5.

7.2 Select a representative piece of susceptor sample to be tested. If the susceptor is part of a package, trim excess material from around the susceptor. Cut the susceptor to fit into the Waldorf cell with the screw seal ring firmly seated against the susceptor surface.

7.3 For susceptors intended for use above and not in contact with the food product, select an acceptably sized petri dish to match the size of the susceptor, proceed through 7.4 and 7.5, and then place the susceptor above contents of the cell with active face down.

7.4 Add 1.0 g of corn oil, or equivalent, to the cell for each 1 cm^2 of susceptor material being tested.

7.5 Place 50 mL of room temperature distilled water and a boiling chip into a 250-mL beaker. Place beaker in center rear of microwave oven.

7.6 Place the cell in the center of the microwave oven. Always position the vessel in the same position for subsequent runs.

7.7 Insert one or more temperature-sensing probes through pre-formed holes in Waldorf cell. Manipulate the probes until they are in contact with the active face of the susceptor material.

7.8 Before proceeding with replicate runs, one must first perform trial runs to determine the extent of water loading necessary to limit the microwave energy exposure of the susceptor to an amount which will result in a temperature that closely approximates or is slightly higher than that attained by the actual product. Adjustment of the water load can be achieved by varying the mass of water in one or more 250-mL beakers or by varying the beaker size to change the water surface area.

7.9 Microwave at full power for the time period used in 5.6, recording the temperature for each probe, preferably at 5-s intervals, but at intervals not to exceed 15 s. Calculate the average from the replicate runs at each recorded time.

7.10 Plot the average temperature as a function of time from 5.6 and 7.3, using the data from the hottest recorded region of the susceptor in both cases.

TABLE 1 Reproducibility of Single-Probe Readings in One Representative Laboratory, °F

NOTE 1—Triplicate analyses of popcorn susceptor in vials with 250 mL of water in a 400-mL beaker.

Time, s	#1	#2	#3	Average	Mean (coefficient of variance)
120	318.1	300.4	321.5	313	2.9
135	324.4	301.4	319.0	315	3.2
150	322.5	294.0	314.8	310	3.9
165	320.5	288.3	308.7	306	4.2
180	316.1	287.1	301.7	302	4.0
195	318.8	287.1	299.4	302	4.3
210	323.5	290.6	300.1	305	4.6
225	326.9	297.2	299.2	308	4.5
240	332.7	301.2	296.6	310	5.2

TABLE 2 Interlaboratory Reproducibility for Temperature Measurement During Preparation of Microwave Popcorn (Ten-Laboratory Study), °F

	3.00 min, mean (coefficient of variance)	3.25 min, mean (coefficient of variance)	3.50 min, mean (coefficient of variance)	3.75 min, mean (coefficient of variance)
Brand #1	356 (12.9)	368 (14.4)	382 (16.5)	387 (16.8)
Brand #2	366 (14.5)	377 (15.6)	394 (15.2)	404 (14.4)
Brand #3	360 (11.1)	368 (12.5)	376 (12.2)	389 (12.1)

7.11 Compare the plots. If the trace from the cell closely approximates or is slightly higher than that for the product during microwave preparation, then the test conditions employed for the cell runs are acceptable for conducting nonvolatile extractives testing for this susceptor application. If the trace is substantially higher or lower than that of the susceptor with product, then adjust the mass or surface area, or both, by changing container size of the water (using a fresh sample of room-temperature distilled water), and repeat 7.9 and 7.10.

TABLE 3 Interlaboratory Reproducibility for Temperature Measurement During Preparation of Microwave Pizza(Five-Laboratory Study), °F

Cook Time	Greased Probe, mean (coefficient of variance)	Ungreased Probe, mean (coefficient of variance)
4.50	373 (9.7)	352 (12.2)
4.75	374 (9.4)	353 (12.2)
5.00	375 (9.6)	356 (12.1)
5.25	365 (11.5)	350 (14.3)
5.50	372 (10.2)	358 (13.4)
5.75	370 (10.8)	355 (14.1)
6.00	375 (10.1)	359 (13.1)

8. Precision and Bias

8.1 Table 1, Table 2, and Table 3 are from a group of collaborative studies based on approximately 700-W microwave ovens intended for home use, made by several commercial manufacturers. Because different microwave ovens have different microwave energy intensity patterns, the interlaboratory data are not necessarily indicative of identical test conditions.

9. Keywords

9.1 extractives, nonvolatile, temperature profiling for; extractives, volatile, temperature profiling for; fluoroptic temperature measurements; fluoroptic thermometry; microwave; microwave cooking temperatures; microwave susceptors; nonvolatile extractives, temperature profiling for; susceptor; susceptors, microwave; temperature measurements, fluoroptic; temperature profile; temperature profiling, microwave susceptors; temperatures, microwave cooking; thermometry; volatile extractives, temperature profiling for