



Institute For Thermal Processing Specialists

TEMPERATURE AND HEAT TRANSFER DISTRIBUTION GUIDELINES FOR PROCESSING IN BATCH AGITATING RETORTS

Various methods and equipment may be used to achieve and verify uniform heating conditions in a retort that ensure product in all areas of the retort receive the scheduled process. Heat transfer distribution studies with temperature measuring devices mounted inside product simulators or product-filled containers may be used to determine heating variations within the retort and to identify the retort cool zone(s) used for process development activities.

The following recommendations are to be considered voluntary guidelines. This does not preclude the application of other methods and equipment for determining whether adequate temperature and heat transfer distributions are achieved in the retort to ensure delivery of the scheduled process. These guidelines have been developed by consensus of the Institute For Thermal Processing Specialists and should be given serious consideration for adoption as methodology by individuals performing temperature and heat transfer distribution studies in batch agitating retorts. These guidelines are applicable for water immersion, water spray, water cascading, and steam-air retorts.

1. PREPARATION: GENERAL PROCESSING EQUIPMENT SURVEY

It is important to develop or establish proper documentation during the survey of the processing equipment that will enable a proper evaluation to be made prior to the process of selecting test retorts. Prior to selection of test retorts, a survey should include examination of the following:

1.1 Steam Supply to the Retorts:

1.1.1 Boiler(s) capacity, pressure, and method of firing.

1.1.2 Retort header pressure. It is important to ensure that adequate steam pressure and volume is available to the retorting system. The survey should be performed during both peak and off use hours.

1.1.3 Pipe size and length, valve size and types, from the main steam line to the retort room.

1.1.4 Size of all connecting steam pipes to the main line noting equipment using steam (e.g., blanchers, exhaust boxes, cappers, etc.)

1.2 Retort Room:

1.2.1 Type, size, and location of each retort; location of instrumentation on each retort.

1.2.2 Steam lines from the main line to each retort, including size of pipes, fittings and valve sizes and types including any pressure reducing valves.

1.2.3 Vent plumbing (purge/air removal) configurations including valve types and sizes, pipe sizes and connections.

1.2.4 Air supply: type, capacity and operating pressure of compressor(s); air dryer type and capacity; filter location(s) and types; header line size, pressure and pressure regulation, if used; heating system, if used.

1.2.5 Water supply: process water supply source, temperature, and controls, if any; cooling water supply source, temperature, and controls, if any.

1.3 Loading Equipment:

1.3.1 Container material, size/dimensions, orientation for retorting and loading configuration.

1.3.2 Maximum number of containers per layer; maximum number of layers per crate; maximum number of crates in each retort.

1.3.3 Hole size and spacing of the base plate, sides of crates and separator sheets if used in the crates or baskets.

1.3.4 Percent open area of the crates and separator sheets, if used.

1.3.5 Orientation of the crates in the retort during processing.

2. SELECTION OF THE TEST RETORT(S)

Serious consideration should be given to testing all retorts on a regular basis to confirm they continue to perform as previously tested and documented. Information taken in the retort room survey and an understanding of plant control, validation, and operating procedures may be used to recommend a reduced testing plan. In any event, the retorts selected for testing should represent those identified as having the greatest potential for diminished delivery of the scheduled process. The reasons for retort selection should be documented in the testing records. New retorts can be presumed to require distribution studies. Similarly, retorts that have undergone extensive repair or redesign can be expected to require distribution studies.

3. TEST RETORT(S) DOCUMENTATION

List, provide a diagram and describe the operation, condition, and calibration status (as necessary) of the following:

- 3.1 Retort Shell:** Physical dimensions and number of crates used in each run. Note the presence and location of any centering guides and/or baffle plates.
- 3.2 Steam Supply from Main Line to Retort:** Pipe size, valve size and type, pressure regulators or reducers and all pipe fittings including steam by-pass pipes.
- 3.3 Steam Introduction to the Retort:** Type and specifications for the steam distribution system including configuration, steam flow piping, number and location of steam injection perforations; steam injection chamber, if applicable.
- 3.4 Heating Medium Control:** Temperature or pressure actuated; controlling thermal element; type and location.
- 3.5 Air Supply:** Entry location and inlet size, control valve size and type, pressure setting and flow rate during testing; availability to supply instruments; indicate if air is heated or air lines are in close proximity to steam or water lines.
- 3.6 Piping and Instrumentation:**
- 3.6.1** Steam spreader (or nozzle) – shape, size, location and configuration; number, size and location of holes in pipe; size of “T”, or any other pipe fittings.
- 3.6.2** Vents – location and size of pipes, also type and size of valve(s).
- 3.6.3** Vent manifold or manifold headers – location and size of all pipes and connecting pipes.
- 3.6.4** Bleeders, mufflers – location, number, size and construction.
- 3.6.5** Drains – location and size.
- 3.6.6** Water supply – location and size of pipes, valve size and type (if applicable), pump and/or spreader size, type and location (if applicable).
- 3.6.7** Water level indicator(s) – type and location.
- 3.6.8** MIG thermometer/reference temperature measuring device (TMD) that conforms to applicable regulations – type and location on the retort; size, type and location of any instrument wells.
- 3.6.9** Pressure sensing device – type, range and location on the retort.

3.6.10 Safety valve(s) – size, type and location.

3.6.11 Additional piping or equipment such as condensate removal systems, etc. which might affect temperature distribution.

3.7 Rotational Equipment: rotational speed indicator and drive system.

3.8 Recording Device: Recorder or recorder/ controller type and description including resolution and parameters recorded.

3.9 For Water Immersion Retorts:

3.9.1 Steam injection points – size, type and location.

3.9.2 Water circulation system – pump type and capacity, inlet/outlet ports location and size, circulation line size; flow meter type and capacity.

3.10 For Steam/Air Retorts:

3.10.1 Steam spreader (nozzle) – size, type and location

3.10.2 Type and description of circulation system for steam/air mixing

3.10.3 Bleeder(s) size, type and location

3.11 For Water Spray and Water Cascading Retorts:

3.11.1 Water spreader(s) – size, type and location.

3.11.2 Water circulation system – pump type and capacity, impeller size, motor size; inlet/outlet ports location and size; circulation line size; flow meter type and capacity.

3.11.3 Steam injection points - size, type and location.

3.11.4 Heat exchanger – use, size and type.

4. TEST EQUIPMENT

Either an external or internal monitoring system may be used.

4.1 External Monitoring System

4.1.1 Thermocouples or other temperature measuring devices of sufficient size, length, number and quality to adequately monitor the heating medium temperatures within the retort.

4.1.2 Data Logger equipped with sufficient channels to adequately monitor and record temperatures within the process delivery system and with sufficiently short scan time to detect temperature variations, if present.

4.1.3 Stuffing Box (Packing Gland) for entry of lead wires into the retort using soft synthetic materials to provide a tight seal without damaging leads.

4.1.4 Slipring to allow for transfer of thermocouple outputs (from a rotating environment) to a stationary electrical contact outside the retort.

4.1.5 Pressure Indicating Device(s), if needed.

4.1.6 Mercury-in-Glass Thermometers/Reference TMDs, if test retort MIG/reference is not to be used.

4.2 Internal Monitoring System

4.2.1 Wireless Temperature Measuring Devices of sufficient size, length, number and quality to adequately monitor the heating medium temperatures within the retort.

4.2.2 Interface module/reader station(s) and software appropriate for programming and reading data from TMDs.

4.2.3 Holders or other suitable devices to hold TMDs firmly in place during retort rotation without influencing distribution.

5. TEST EQUIPMENT STANDARDIZATION

5.1 Retort Thermometer: The retort mercury-in-glass (MIG) thermometer/reference TMD should conform to the applicable Federal Regulations or appropriate international standards and should have been checked for accuracy against a known traceable thermometer within the past year.

5.2 Temperature Measurement System including either the external monitoring system (data logger, thermocouples, extension wires) or internal monitoring system (wireless TMDs).

5.2.1 Prior to conducting the actual distribution study, standardization or calibration of test equipment should be performed.

5.2.2 Check the accuracy of each monitoring lead or device against the known accurate retort MIG thermometer/reference device or calibration standard. Any single lead/device should agree within 0.5 degree F (0.3 degree C) of the reference instrument. The range for all leads/devices should be not more than 1 degree F (0.6 degree C). Any lead/device which deviates from the above criteria should not be used until corrective action is performed which results in meeting the established criteria. To

provide a secondary reference for data evaluations, the lead/device in closest agreement with the known accurate MIG thermometer/reference may be attached to the thermometer/reference probe.

5.2.3 One acceptable method of calibration is to bundle all TMDs or thermocouples, extensions and connections assembled as they will be used under actual test conditions and locate them in close proximity to the known accurate MIG thermometer/reference probe, taking care not to inhibit heating medium flow past devices or the reference probe. Bring the test retort up to the temperature and pressure to be used during the distribution tests and allow the entire system to equilibrate.

5.2.4 Alternatively, TMDs may be calibrated off-line in an established calibration program within the temperature range to be used during distribution tests.

5.2.5 Standardization or calibration of test equipment post-test is recommended.

5.2.6 In order to meet the above calibration criteria and ensure the accuracy of the test results, consideration should be given to minimizing errors inherent in any component of the temperature measuring system. For example, the number of junctions from the thermocouple tip to data logger should be minimized. The use of special limits of error, premium-grade thermocouple wire for all thermocouple leads and extensions should be considered.

6. PLACEMENT OF THE TEMPERATURE MEASURING DEVICES IN THE RETORT

6.1 Location of Monitoring Devices in the Retort: Leads or TMDs should be placed in the following locations in the retort:

6.1.1 In close proximity to the MIG thermometer/reference probe without impeding retort rotation.

6.1.2 In close proximity to the temperature controller, unless the MIG/reference and controller probes are located together.

6.1.3 A minimum of three devices, each located in separate areas of each basket or crate; leads/TMDs should be placed so the measuring junctions (tips) are not in direct contact with containers or other material surfaces.

6.1.4 Depending upon the processing system and heating medium, it may be necessary to place additional leads/TMDs at other locations within the vessel to adequately assess any cool zone(s) in the retort. Symmetry, rotation, and rotational plane effects in the retort should be considered.

6.1.5 All leads/TMDs must be securely fastened in place to prevent damage and unplanned movement during retort rotation.

6.2 Record of Monitored Locations: A schematic drawing to show the placement of all monitoring devices within the retort should become part of the records for the distribution tests.

7. PREPARING THE TEST CRATES OR BASKETS WITH CONTAINERS

7.1 Container Size: Select the container size processed in the retorts, usually the smallest, that will yield the worst-case situation for the operation. In some cases, each container size, type, configuration, position and orientation will require testing to determine the worst case situation.

7.2 Container Contents: For convection heating products, water or the fastest heating product processed is satisfactory. For conduction heating products, consideration should be given to selecting the worst-case product processed in the retort. Document the reasons for product selection in the testing records.

7.3 Container Placement: Containers are placed in the crate or baskets in a manner that is equivalent to the worst-case situation under the commercial operation. This may need to be determined through observation and testing. If separator or divider sheets are used between the layers of containers, then the sheets having the smallest percent total open area should be used for testing. If additional sheets are used either on the top or bottom of the load, this procedure must be duplicated for the test.

7.4 Loading Configuration: Crate or basket loading configuration at the extremes of those expected in production should be tested to determine which yields the worst-case situation. The smallest anticipated partial load should be compared to full load conditions noting uniformity and temperature control and stability throughout the retort.

7.5 Operating Procedures: Normal commercial operating procedures testing the extremes of allowable ranges to examine the effects of loading, overpressure, and agitation should be followed.

8. TEMPERATURE DISTRIBUTION TEST

8.1 Set Up: Verify the retort survey is accurate and complete.

8.2 Data Collection Points:

8.2.1 The following should be monitored and recorded during the test:

8.2.1.1 Controller temperature set point including overshoots or changes during processing.

8.2.1.2 "0" time or time "steam on".

8.2.1.3 Temperature of process water supply, if preheated.

8.2.1.4 Fill time (displacement) in those systems dropping water from a storage drum or tank into the working processing vessel.

- 8.2.1.5** Water level in process vessel in relation to the container position at the top of the vessel during rotation.
 - 8.2.1.6** Time and temperature when the drain is closed, if it is open during a portion of the vent.
 - 8.2.1.7** Time and temperature of the retort when the vent closes, taken from the MIG thermometer or reference measuring device.
 - 8.2.1.8** Time when the reference temperature measuring device reaches the processing temperature set point.
 - 8.2.1.9** Time when the controller (if applicable) advances to the “cook” cycle in the program.
 - 8.2.1.10** MIG thermometer/reference TMD readings – at sufficient intervals, including the time the device reaches the processing temperature set point.
 - 8.2.1.11** Monitor rotation rate at sufficient intervals using an accurate stopwatch, including any points where rate changes occur during processing.
 - 8.2.1.12** Retort pressure - readings at sufficient intervals or by continuous charting including the time retort reaches processing temperatures – required for steam-air retorts, desirable for other retort types.
 - 8.2.1.13** Water temperature for heating and/or cooling, as appropriate.
- 8.2.2** The following points are important and are highly recommended to be monitored and recorded during the test:
- 8.2.2.1** Retort steam header pressure and temperature (if superheated steam is a concern) and/or steam pressure at the end of the spreader.
 - 8.2.2.2** Time when the monitoring devices reach processing temperature set point.
 - 8.2.2.3** For water spray/cascading or water immersion retorts, water recirculation rate using a suitable flow meter.
 - 8.2.2.4** Ambient temperature and climatic conditions.
 - 8.2.2.5** Operating activity of other retorts during the time of testing.

8.3 Conducting the Test:

8.3.1 Either the internal or external monitoring system should record the temperature of each monitoring device just prior to “0” or “steam on” time and at sufficient intervals, not to exceed one minute, throughout the test. The temperature log should become part of the records for the test.

8.3.2 Critical points should be documented at intervals of sufficient frequency to describe and verify retort operating parameters during the test. This information becomes part of the test records and should include the temperature recording chart(s), pressure readings or chart, any flow rate records, MIG thermometer/reference TMD readings and other data gathered that have been identified as critical data collection points. The retort process control generated records may be used to supplement manual test observations and recordings.

8.3.3 The test should extend for at least as long as the typical process hold time after the retort control system has stabilized and a definite temperature profile has been established or all monitoring devices have reached a steady state condition.

8.3.4 Retort cooling phase temperatures should be recorded until test product temperatures are 200 degrees F (94 degrees C) or lower. This is especially important if product cooling lethality will be based upon actual retort cooling profiles in developing scheduled processes.

8.3.5 A post-test inspection should be conducted to assure that the condition of the measuring sensors, test containers, and other attributes of the retort load has not changed during testing.

8.3.6 Ideally, no monitoring device should read more than plus or minus one degree F (0.6 degree C) from the reference monitoring device at the time it first indicates the processing temperature set point has been reached. Situations or conditions that do not meet these criteria should be evaluated by a thermal processing specialist.

9. HEAT DISTRIBUTION TESTING IN THE PRODUCT MATRIX (LETHALITY MAPPING)

Temperature distribution testing specified in previous sections of these guidelines using bare probes in the retort environment focus on come-up and cook portions of the processing cycle. Temperature uniformity in these portions of the cycle may not correlate to uniform heat transfer into containers throughout the retort. The effects of container location in the center or the periphery of the load are not considered in temperature distribution testing, nor are any affects of fastest to heat containers compared to those that are fastest to cool. In order to adequately determine any cool zone(s) in the retort, conducting lethality mapping studies by measuring the uniformity of delivered lethality throughout the retort during the entire processing cycle is recommended.

Lethality mapping allows for identification of one or more cool zones as well as one or more hot zones throughout the retort. The range or lethality spread among locations may also be assessed. If desired, lethality data may be separated into that achieved during come-up and cook versus that achieved in cool. This information is valuable in assessing the affects on nutrients and the product's

physical stability throughout the retort load. Modifications to the retort or processing cycle to reduce or minimize the lethality differential throughout the load are also possible.

Any cool zones identified in lethality mapping may be used to conduct subsequent heat penetration and process development studies.

Lethality mapping is also a useful tool if the heat transfer characteristics of the heating medium are suspect. For example, if a steam/air retort does not produce a uniform mixture, there may be areas in the retort that have a high air to steam ratio. Containers heating at a slower rate than expected, as determined by reduced lethality accumulation or larger heating rate index, would indicate where these areas are located.

9.2 Set Up:

9.1.1 Prepare test crates or baskets with containers as outlined in section 7 of these guidelines.

9.1.2 Each lead or TMD must be securely fastened **inside** the test container so that the measuring junction (tip) is held in the container cool zone.

9.1.3 Filled test containers with internally-mounted leads or TMDs should be placed in the following locations in the retort:

9.1.3.1 In close proximity to the MIG thermometer/reference TMD probe without impeding retort rotation.

9.1.3.2 In close proximity to the temperature controller, unless the MIG/reference TMD and controller probe are located together.

9.1.3.3 At a minimum of five monitoring devices, each located in separate areas of each basket or crate. Symmetry, rotation, and rotational plane effects in the retort should be considered.

9.1.3.4 In areas where cooling is anticipated to be most rapid.

9.1.3.5 In cool zones determined during temperature distribution testing.

9.1.3.6 In areas expected to heat quickly or cool slowly if hot zones are to be determined.

9.1.4 Record of Monitored Locations: A schematic drawing to show the placement of all monitoring devices within the retort should become part of the records for lethality mapping tests.

9.2 Data Collection Points: Follow steps outlined in section 8.2 of these guidelines.

9.3 Conducting the Test: Follow steps outlined in sections 8.3.1 through 8.3.5 of these guidelines.

9.4 Evaluating Data:

9.4.1 Calculate total delivered lethality for each test container.

9.4.2 If desired, separate lethality data into that achieved during come-up and cook steps from that achieved during cooling steps.

9.4.3 If test containers have also been placed in the expected hot zone(s), the lethality differential between cool and hot zones may be compared. This information is valuable in assessing:

9.4.3.1 Affects on nutrients and the product's physical stability through the retort load.

9.4.3.2 Possible modifications to the retort or processing cycle to reduce or minimize the lethality differential throughout the retort load.

9.4.4 Determine product cool zone(s) for the tested package/product combination. The cool zone may be determined based on the lowest delivered lethality at the end of the cook portion of the cycle or at the end of the entire cycle including the cooling portions.

9.4.5 All process determination (heat penetration) studies should be conducted placing test containers in the determined product cool zone(s) from lethality mapping studies.

The Institute for Thermal Processing Specialists is a non-profit organization established exclusively for the purpose of fostering education and training for those persons interested in procedures, techniques and regulatory requirements for thermal processing of all types of food or other materials, and for the communication of information among its members and other organisations.

Part of the mandate of IFTPS Technical Committees is to develop guidelines for carrying out the work of thermal processing specialists. This guideline was prepared by the Committee on Temperature Distribution and reviewed extensively by members of the Institute. The document was approved for publication in December, 2008 by the IFTPS Board of Directors.

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