Designation: F895 – 11 (Reapproved 2016)

Standard Test Method for Agar Diffusion Cell Culture Screening for Cytotoxicity[1]

This standard is issued under the fixed designation F895; 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 test method is appropriate for materials in a variety of shapes and for materials that are not necessarily sterile. This test method would be appropriate in situations in which the amount of material is limited. For example, small devices or powders could be placed on the agar and the presence of a zone of inhibition of cell growth could be examined.

1.1.1 This test method is not appropriate for leachables that do not diffuse through agar or agarose.

1.1.2 While the agar layer can act as a cushion to protect the cells from the specimen, there may be materials that are sufficiently heavy to compress the agar and prevent diffusion or to cause mechanical damage to the cells. This test method would not be appropriate for these materials.

1.2 The L-929 cell line was chosen because it has a significant history of use in assays of this type. This is not intended to imply that its use is preferred, only that the L-929 is an established cell line, well characterized and readily available, that has demonstrated reproducible results in several laboratories.

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

1.4 *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]

F748 Practice for Selecting Generic Biological Test Methods for Materials and Devices

2.2 *ATCC Document:*

American Type Culture Collection, (ATCC) Catalogue of Strains II[3]

USP Negative Control Plastic Reference Standard[4]

3. Summary of Test Method

3.1 Cell cultures are grown to a monolayer in culture dishes. The medium is aspirated and replaced with an agar-containing medium that is allowed to solidify. Test control articles are placed on the agar surface to evaluate the cytotoxic properties of a given material or device. Toxic components in the test article can diffuse into the culture medium, forming a concentration gradient and adversely affecting cells at varying distances from the test article. This method is well suited for low-density materials (film, paper, and so forth), powders, liquids, and high-density materials that could physically damage the cells if placed in direct contact with the cell monolayer.

4. Significance and Use

4.1 This test method is useful for assessing the cytotoxic potential of new materials and formulations and as part of a quality control program for established medical devices and components.

4.2 This test method assumes that assessment of cytotoxicity provides useful information to aid in predicting the potential clinical applications in humans. Cell culture methods have shown good correlation with animal assays and are frequently more sensitive to cytotoxic agents.

4.3 This cell culture test method is suitable for incorporation into specifications and standards for materials to be used in the construction of medical devices that are to be implanted into the human body or placed in contact with tissue fluids or blood on a long-term basis.

4.4 Some biomaterials with a history of safe clinical use in medical devices are cytotoxic. This test method does not imply that all biomaterials must pass this assay to be considered safe for clinical use (Practice F748).

5. Apparatus

5.1 The following apparatus shall be used:

---

[1] This test method is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.16 on Biocompatibility Test Methods.

Current edition approved April 1, 2016. Published June 2016. Originally approved in 1984. Last previous edition approved in 2011 as F895 – 11. DOI: 10.1520/F0895-11R16.

[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.

[3] Fourth edition, 1983, is available from American Type Culture Collection, 12031 Parklawn Dr., Rockville, MD 10892. Library of Congress No. 76-640122.

[4] *U.S. Pharmacopeia*, current edition, Rockville, MD.

5.2 *Incubator,* which maintains the cultures at 37 ± 2°C, 5 ± 1 % CO_2, and greater than 90 % relative humidity.

5.3 *Water Bath,* capable of maintaining a temperature of 37 ± 2°C and 45 ± 2°C.

5.4 *Microscope,* with inverted phase contrast optics and magnifications of 40, 100, and 200×.

5.5 *Clinical Centrifuge,* capable of attaining 1000 xg.

5.6 *Sterile, Disposable 150-cm^2 Tissue Culture Flasks.*

5.7 *Sterile, Tissue Culture Dishes,* 35 mm in diameter and 10 mm deep.

NOTE 1—Plastic dishes are recommended because they provide a flat surface that promotes the formation of a uniform monolayer of cells.

5.8 *Sterile, Disposable, Centrifuge Tubes.*

5.9 *Sterile Pipettes,* 1, 5, and 10 mL.

5.10 *Filter Disks,* 10 mm in diameter for evaluation of liquids.

NOTE 2—Millipore AP2501000 filter disks have been found satisfactory for use in cytotoxicity evaluations because they elicit no cytopathic effect. Other filter disks that do not elicit a cytopathic effect may also be used.

NOTE 3—A laminar flow work area capable of filtering out 99.99 % of all particles greater than 0.3 µm in diameter, or a Class 100 clean room may be necessary to prevent contamination of cultures.

6. Reagents

6.1 The following reagents shall be used:

6.1.1 *For Cell Culture Maintenance,* 1× Media. Minimum Essential Medium (MEM) is prepared by mixing 90 mL of Eagle's MEM (with Earle's salts, without L-glutamine), adjusting the solution to pH of 7.15, and adding 5 to 10 mL of fetal bovine serum, and 1 mL of 100× nonessential amino acids (L-glutamine).

6.1.1.1 Opened containers of prepared MEM may be stored at a temperature of 2 to 8°C for periods of not more than two weeks. Glutamine is omitted from this formulation to maximize the shelf life. Immediately before use, 1 mL of L-glutamine solution (see 6.1.3) is added to each 100 mL of MEM.

6.1.1.2 Antibiotics, such as penicillin G10 000 I.U./mL, and streptomycin 10 000 I.U./mL, may be added to the medium to reduce the incidence of bacterial contamination. Use 1 mL of antibiotic per 100-mL media. Care shall be taken to ensure that the antibiotics do not have an adverse effect on the viability of the cell cultures.

6.1.2 *For Agar Media Overlay,* to prepare 2× Media (100-mL final volume). Twice concentrated (2×) MEM is prepared by mixing 20 mL of 10× Eagle's MEM (with Earle's Salts without L-glutamine), 0.22-g sodium bicarbonate (buffer) and sterile distilled water to bring to 70 mL. Adjust the pH to 7.15. Add 20-mL fetal bovine serum and 2 mL of 100× nonessential amino acid (L-glutamine). Bring to final volume (100 mL) with sterile distilled water. Filter sterilize the 2× media. Mix with equal amounts of sterilized 3 % agar nobel to give the final concentration of the media as 1×.

6.1.3 *L-Glutamine Solution* (*Lyophilized*), 29.2 mg/mL. Rehydrate with sterile distilled water. (Store frozen.)

6.1.4 *Hanks' Balanced Salt Solution,* calcium- and magnesium-free (store at room temperature).

6.1.5 *Trypsin,* 0.1 % solution in Hanks' balanced salt solution or calcium- and magnesium-free, phosphate-buffered saline (store frozen).

6.1.6 *Water,* sterile, deionized, or distilled water should be used.

6.1.7 *Noble Agar,* 3 %.

6.1.8 *Neutral Red Stain,* 0.01 % by weight in phosphate-buffered saline.

6.2 All reagents shall be tissue-culture grade or equivalent.

6.3 Reagents shall be reconstituted in accordance with the manufacturer's directions, using aseptic technique.

7. Cell Culture

7.1 Cell cultures used in this assay shall be the ATCC, CCL I NCTC clone 929 strain (clone of Strain L, mouse connective tissue) designated L-929. Other suitable validated cell lines may be considered.

8. Control Materials

8.1 Prepare negative control specimens in accordance with Section 10 from a material that consistently elicits negligible cellular response in this assay (for example, USP Negative Control Plastic Reference Standard).

8.2 Prepare positive control specimens in accordance with Section 10 from a material that consistently elicits a moderate and reproducible degree of cytotoxicity (for example, an aqueous solution of phenol (0.45 ± 0.05 % by volume), or other material producing a known cytotoxic response, for example, latex rubber).

8.2.1 Use an aqueous solution of phenol to give a diffuse reaction of cellular degeneration and sloughing; a latex rubber will give a zone of toxicity.

8.2.2 Take care when preparing aqueous solutions of phenol to ensure the homogeneity of the solution since phase separations may occur.

8.2.3 Latex rubber is a widely used control material that has demonstrated reproducible results in several laboratories.

9. General Technique

9.1 Use aseptic technique throughout this assay to minimize microbial contamination.

NOTE 4—Mouth pipetting should not be used to transfer cells, medium, or reagents.

9.2 Warm all solutions and materials to a temperature of 37 ± 2°C before being placed in contact with cells.

9.3 Wash all glass vessels thoroughly with a cleaning solution and rinse thoroughly with copious amounts of deionized water.

9.4 Clean all work surfaces with a disinfectant solution before use.

9.5 Record the culture history of the cells.

9.6 Stock cultures should be periodically screened for mycoplasma contamination.

10. Specimen Preparation

10.1 Sterilize all specimens by a method appropriate to the end use of the device.

10.2 Where a device is sufficiently small (see 10.3 and 10.4) to fit into the culture dish leaving an adequate margin of cells for evaluation, use the entire device as a specimen.

10.3 Cut large solid materials and devices in cross section to obtain a flat surface having an area of 100 to 250 mm^2 to be placed in direct contact with the agar surface.

10.4 Prepare specimens of rod or tubing or of rod- or tube-shaped devices as follows:

10.4.1 Where the diameter is less than 6.4 mm, cut 5 to 15 mm in length.

10.4.2 Where the diameter is 6.4 to 15 mm, cut 2 to 8 mm in length.

10.4.3 Where the diameter exceeds 15 mm, prepare cross sections as described in 10.3.

10.5 Obtain specimens from larger medical items from locations with relatively large cross sections to expose interior material.

10.6 If a device is constructed of two or more materials that are intended to contact body fluids or tissues, either cut the test specimen from the materials' interface or test separate specimens of each material or both.

10.7 Prepare specimens for evaluating the cytotoxicity of liquids or extracts by saturating a sterile filter disk and allowing the excess liquid to drain off while maintaining asepsis. Use the saturated filter disk as a test specimen.

NOTE 5—When ethylene oxide or other chemical sterilants are used, adequate aeration time to permit dissipation of residues which may adversely affect the results recorded in this assay should be determined.

NOTE 6—In general, specimens should be cleaned to remove any residues from specimen preparation and sterilized after they have been cut to size. If the specimen is very hard (for example, ceramics), care should be taken to remove the residues that may be left on the freshly cut surface by the cutting tool. When evaluating the cytotoxic potential of medical materials or devices that are contained in the final sterile package, resterilization, further processing, or delay between the time of opening the package and starting the test must be avoided. With small items, the entire content of the sterile package may be used as the test specimen. When the size of the sterile packaged item is too large, an appropriate, representative, small-sized specimen must be obtained. The application of this assay to items in the final sterile package is limited to items that are small or can be cut and reshaped using aseptic technique.

10.8 Absorbant materials tested in this method shall be prewetted with culture medium to prevent loss of water from the agar and subsequent cellular damage.

11. Cell Culture Maintenance

11.1 Use the following procedures to maintain the cells by serial subculture:

11.2 Aspirate the medium from a 150-cm^2 cell culture flask containing a near-confluent monolayer.

11.3 Rinse the cells with a sufficient volume (for example, 5 to 10 mL) of Hanks' balanced salt solution to remove residual serum.

11.4 Aspirate the rinse solution.

11.5 Add a sufficient volume of trypsin solution (0.1 %) to the flask to cover the cell monolayer (approximately 5 mL).

11.6 Incubate for 5 to 10 min to suspend the cells.

11.7 Transfer the cell suspension to a centrifuge tube.

11.8 Centrifuge at 1300 xg for 6 min.

11.9 Discard the supernatant.

11.10 Resuspend the cells in 10 ± 0.1 mL of fresh medium and mix the suspension thoroughly.

11.11 Distribute the cell suspension equally among each of two to eight 150-cm^2 tissue culture flasks.

11.12 Add a sufficient volume of fresh medium so that each flask will contain approximately 50 mL.

11.13 Change the medium every two to three days until the monolayer is nearly confluent, then repeat Steps 11.2 – 11.12.

12. Cell Layer Preparation

12.1 Prepare confluent cell monolayers as follows:

12.2 Follow Steps 11.1 – 11.9 to prepare a cell suspension.

12.3 Add 2.0 ± 0.1 mL of medium to each culture dish.

12.4 Using a sterile 10-mL serological pipette, add five to seven drops of cell suspension to each dish. Rotate the dishes to ensure an even distribution of cells.

12.5 Incubate until a near-confluent monolayer has formed, as observed by microscopic examination.

NOTE 7—The formation of a near-confluent monolayer usually requires three to five days. By counting cells with a hemacytometer (to ensure the concentration of the inoculum), the time required for monolayer formulation may be regulated. A cell concentration of 1.3×10^5 cells/mL will give a consistent time of 24 h.

12.6 If the cell suspension remains unused after Step 12.3, a subculture may be prepared by adding 9 mL of fresh medium to each millilitre of cell suspension in a cell culture flask with a surface area of approximately 3 cm^2 for each millilitre of diluted cells and incubating it until a near-confluent monolayer has formed, as determined by microscopic examination.

13. Test Procedure

13.1 Perform the agar diffusion cytotoxicity assay as follows:

13.2 Microscopically examine the cell cultures and reject any in which the cell monolayer is not of correct confluency or the cells show signs of granulation or sloughing.

13.3 Autoclave 3 % Nobel Agar for 15 min at 121°C.

13.4 Place the autoclaved agar into a 45°C waterbath and allow it to cool to 45°C.

13.5 Place 2× MEM into a 45°C waterbath and allow it to warm to 45°C. Do not allow the medium to remain at 45°C longer than 1 h.

13.6 Mix equal volumes of the 2× MEM and 3 % Nobel Agar thoroughly. Allow the mixture to cool to approximately 39°C.

13.7 Aspirate the medium from all acceptable cultures, and replace it with 2.0 mL of agar medium.

13.8 Place the cultures on a flat surface to solidify at room temperature.

13.9 Place a single test or control specimen in each dish in contact with the agar surface. Prepare duplicate cultures for each test material and both positive and negative controls.

NOTE 8—This method may be modified by using larger culture dishes to accommodate the positive and negative control specimens in the same dish as the test specimen. Quantities of cells and reagents must be increased appropriately if larger dishes are used.

13.10 Incubate all cultures for 24 ± 1 h.

13.11 Mark the outline of the specimen on the bottom of the culture dish with a permanent marker, and then remove the specimen.

13.12 Add 2 mL of Neutral Red solution to each dish and incubate for 1 h.

13.13 Pour off the Neutral Red solution and examine each culture microscopically under and around each control and test specimen.

14. Evaluation of Results

14.1 A cell culture shall be deemed to show a cytotoxic effect if microscopic examination reveals malformation, degeneration, sloughing, or lysis of the cells within the zone or a moderate to severe reduction in cell layer density.

14.2 The Zone Index (Table 1) measures the clear zone in which cells do not stain with neutral red.

14.3 The Lysis Index (Table 2) measures the number of cells affected within the zone of toxicity.

TABLE 1 Zone Description

Zone Index	Description of Zone
0	No detectable zone around or under specimen
1	Zone limited to area under specimen
2	Zone extends less than 0.5 cm beyond specimen
3	Zone extends 0.5 to 1.0 cm beyond specimen
4	Zone extends greater than 1.0 cm beyond specimen but does not involve entire dish
5	Zone involves entire dish

TABLE 2 Lysis Description

Lysis Index	Description of Zone
0	No observable cytotoxicity
1	Less than 20 % of zone affected
2	20 to 39 % of zone affected
3	40 to 59 % of zone affected
4	60 to 80 % of zone affected
5	Greater than 80 % of zone affected

NOTE 9—A slight reduction of cell layer density is acceptable, provided there is no other evidence of cytotoxicity as specified in 14.1.

14.4 If, for a given set of specimens, a cytotoxic effect is observed for the negative controls or no cytotoxic effect is elicited by the positive controls, the results for that set of specimens shall be considered invalid.

15. Report

15.1 The report of the assay results shall include, but not be limited to, the following information:

15.2 Test date.

15.3 Cell strain used.

15.4 Medium used (noting whether antibiotics were used).

15.5 A description of all test and control specimens, including:

15.5.1 Material or device name (including ASTM specification number, where appropriate).

15.5.2 Lot or batch number.

15.5.3 Source of supply.

15.5.4 Size and method of preparation.

15.5.5 Method of sterilization.

15.6 Numerical values for Zone Index and Lysis Index.

15.7 Any other pertinent observations, including any deviations from the exact method described herein.

16. Precision and Bias

16.1 Quantitative precision and bias have not yet been determined for this standard.

17. Keywords

17.1 agar diffusion; biocompatibility; cell culture; cytotoxicity testing

APPENDIX

(Nonmandatory Information)

X1. RATIONALE

X1.1 Laboratory cell culture methods provide a rapid method for assessment of cytotoxic potential of both finished medical devices and materials used in their construction. The agar diffusion method is but one of several such techniques that are in common use. The cell culture method described in this standard is a modification of methods that have been routinely used for decades. A positive control that produces a cytopathic effect and a negative control that produces no cytopathic effect are assayed with each test to assure that the cell cultures have expected cytotoxicity responses. Test results are considered valid only when the expected responses for both controls are obtained.

REFERENCES

(1) Guess, W. L., Rosenbluth, S. A., Schmidt, B., and Autian, J., "Agar Diffusion Method for Toxicity Screening of Plastics on Cultured Cell Monolayers," *Journal of Pharmaceutical Science*, Vol 54 , 1965, pp. 1545–1547.

(2) Wilsnack, R. E., Meyer, F. S., and Smith, J. G., "Human Cell Culture Toxicity Testing of Medical Devices and Correlation to Animal Tests," *Biomaterials Medical Devices and Artificial Organs*, Vol 1, 1973, pp. 543–562.

(3) Autian, J., "New Fields of Plastic Toxicology—Methods and Results," *Critical Reviews in Toxicology*, Vol 2, CRC Press, Inc.