



Standard Guide for Evaluating Water-Miscible Metalworking Fluid Foaming Tendency¹

This standard is issued under the fixed designation E3265; 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 guide provides an overview of foaming tendency evaluation protocols and their appropriate use.

1.2 ASTM Test Methods D3519 and D3601 were withdrawn in 2013. Although each method had some utility, neither method reliably predicted in-use foaming tendency. Since Test Methods D3519 and D3601 were first adopted, several more predictive test protocols have been developed. However, it is also common knowledge that no single protocol is universally suitable for predicting water-miscible metalworking fluid (MWF) foaming tendency.

1.3 Moreover, there are no generally recognized reference standard fluids (either MWF or foam-control additive). Instead it is important to include a relevant reference sample in all testing.

1.4 The age of the reference and test fluid concentrates can be an important factor in their foaming behavior. Ideally, freshly prepared concentrates should be held at laboratory room temperature for at least one week before diluting for foam testing. This ensures that any neutralization reactions have reached equilibrium and enables microemulsions to reach particle size equilibrium. During screening tests, it is also advisable to test fluids after the concentrates have been heat aged and subjected to freeze/thaw treatment.

1.5 The dilution water quality can have a major impact on foaming properties. In general, fluid concentrates diluted with hard water will foam less than those diluted with soft, deionized, or reverse osmosis water. Screening tests using the expected range of dilution water quality are highly recommended.

1.6 The temperature of the tested fluids can have a major impact on foaming properties. In general, test fluids should be held and tested at temperatures that closely mimic the real-world application and process.

¹ This guide is under the jurisdiction of ASTM Committee E34 on Occupational Health and Safety and is the direct responsibility of Subcommittee E34.50 on Health and Safety Standards for Metal Working Fluids.

Current edition approved April 1, 2021. Published April 2021. Originally approved in 2020. Last previous edition approved in 2020 as E3265 – 20. DOI: 10.1520/E3265-21.

1.7 Cleanliness of test apparatus is critical during foam evaluation testing. Traces of residue on labware can significantly impact the observed foaming tendency of a test fluid. Best practice is to clean any glassware or other vessels using some version of a chemical cleaner that will alleviate any risk of cross contamination.

1.8 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.9 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

- 2.1 *ASTM Standards*:²
 - D3519 Test Method for Foam in Aqueous Media (Blender Test) (Withdrawn 2013)³
 - D3601 Test Method for Foam In Aqueous Media (Bottle Test) (Withdrawn 2013)³
 - E2523 Terminology for Metalworking Fluids and Operations

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this method, refer to Terminology E2523.

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 The last approved version of this historical standard is referenced on www.astm.org.

*A Summary of Changes section appears at the end of this standard

3.1.2 *foam, n*—in liquids, a collection of bubbles formed in or on the surface of a liquid in which the air or gas is the major component on a volumetric basis.

3.1.3 *foam break, n*—in foaming tendency testing, the change in total volume occupied by bubbles during a specified test period.

3.1.3.1 *Discussion*—The total bubble volume is a function of individual bubble size and the number of bubbles present. Consequently, foam break can reflect reduction of the volume of individual bubbles, decrease in the number of bubbles present, or a combination of both.

3.1.4 *foam stability, n*—in foam testing, the amount of static foam remaining at specified times following the disconnecting of the air supply.

3.1.5 *foaming tendency, n*—in foam testing, the amount of static foam immediately before the cessation of air flow.

3.1.6 *shear stress, n*—the motivating force per unit area for fluid flow.

3.1.7 *sparge, v*—a process of delivering a chemically inert gas through fluids to displace materials for the purpose of mixing.

3.1.7.1 *Discussion*—In MWF foam testing, most commonly the inert gas is filtered or unfiltered air from a laboratory or building compressor, or from a vendor-supplied compressed gas cylinder.

4. Significance and Use

4.1 The process of recirculating MWFs entrains air bubbles which can accumulate, forming foam.

4.2 Optimally, air bubbles burst open quickly after they are created. However, air bubble persistence is affected by MWF chemistry and the mechanisms by which energy is introduced into recirculating MWFs.

4.2.1 The primary mechanisms imparting energy into recirculating MWFs are:

4.2.1.1 *Turbulent Flow*—The high velocity (typically $>0.75 \text{ m}^3 \text{ min}^{-1}$; $>200 \text{ gal min}^{-1}$).

4.2.1.2 *Impaction*—Energy generated when MWF strikes the tool-workpiece zone.

4.2.1.3 *Centrifugal Force*—MWF moved by the force of rotating tools or work pieces.

4.3 When air bubbles persist, they tend to accumulate as foam. Persistent foam can:

4.3.1 Inhibit heat transfer;

4.3.2 Cause pump impeller cavitation;

4.3.3 Foul filters;

4.3.4 Overflow from MWF sumps;

4.3.5 Prevent proper lubrication;

4.3.6 Contribute to MWF mist formation, including bio-aerosol dispersion; and

4.3.7 Contribute to safety and hygiene hazards in the plant.

4.4 To prevent the adverse effects of MWF foam accumulation, chemical agents are either formulated into MWF concentrate, added tankside, or both.

4.5 Laboratory tests are used to predict MWF foaming characteristics in end-use applications. However, no individual test is universally appropriate.

4.6 This guide reviews test protocols commonly in use to evaluate end-use diluted MWF foaming tendency and the impact of foam-control agents on MWF foaming tendency.

5. Foam Formation Theory

5.1 Foam is a dispersion of a gas phase in a liquid system. Air is introduced into the system mechanically or chemically to create the gas phase. Foam accumulation is related to stabilization of the thin film of liquid that outlines the gas bubble, also known as the lamella.

5.2 In order for gas to escape, bubbles must coalesce, rise, drain, and burst at the surface. Foam is stabilized in the liquid via several mechanisms dependent on the system and application type.

5.2.1 *Surface Viscosity*—Increased structure in a liquid slows drainage and causes higher foaming; the foam film breaks when film thickness falls below a minimum value, dependent on the system.

5.2.2 *Electrostatic Repulsion and Steric Hindrance*—Occurs due to the nature of emulsifiers and surfactants present which contain hydrophilic and hydrophobic groups. They tend to stabilize gas bubbles within the liquid and at the surface of the liquid causing stable foam.

5.3 Specific viscosity properties and the use of surfactants and emulsifiers are essential to water-miscible metalworking fluids. In order to reduce foam tendency, it is important to formulate with these components carefully as well as consider the use of defoamers for high-foam systems.

6. Metalworking Fluid Foam Tendency Evaluation Protocols

6.1 *Blender Test*:

6.1.1 *Concept*—A blender test is a foam collapse test performed by exposing the sample to a very high amount of shear stress for a short period of time.

6.1.1.1 Foam control effectiveness is a function of the maximum foam volume and time required for the foam to disappear (break).

6.1.1.2 The most effective control is reflected in minimum initial foam volume and a short time for the foam to break completely.

NOTE 1—The terms “minimum” and “short” are subjective and situational. They depend on the application and user’s operational objectives. Consequently, neither a volume nor time interval can be specified here.

6.1.2 *Apparatus*—Either a laboratory grade or kitchen blender and a timer.

6.1.2.1 Laboratory grade blenders are best suited for testing when there is a need to compare results taken at different points in time (for example, for periodic quality control testing).

6.1.2.2 Typical kitchen blenders are typically less expensive than laboratory grade blenders but are sufficient for comparing the foaming tendencies of multiple samples as a single test series.

6.1.3 Protocol Summary:

6.1.3.1 An aqueous MWF dilution to be tested is dispensed into a blender vessel which is then sealed.

6.1.3.2 The blender is then run at a high speed for a specified time using a timer; a typical blending time is 60 s.

NOTE 2—Blender speeds vary among makes and models. Typically, high speed implies ≥ 1000 rpm.

NOTE 3—The setting used for speed can be adjusted based on the application and type of shear, for example liquefy or setting 8.

6.1.3.3 A timer is started immediately after blending is stopped. This is the rest period during which the sample is permitted to stand undisturbed.

6.1.3.4 During the rest period the foam volume or height is recorded at specified time intervals, such as 30 s, 60 s, 120 s, etc.

NOTE 4—Some blenders are graduated and make volume measurements practical. Others are not. If the blender is not graduated, its contents may be transferred to a graduated cylinder for volume measurement. Alternatively, a ruler may be used to observe foam column height.

6.1.3.5 The most effective control is reflected in minimum initial foam volume and minimal time for the foam to break completely (see **Note 1**).

6.1.4 Blender testing can vary by vessel configuration, shear stress (blender speed and blade configuration), and number of seconds stress is applied.

6.1.4.1 At the end of the blending period the dilution may be left in the blender or immediately transferred to a graduated cylinder.

6.1.4.2 A graduated cylinder typically allows for more accurate foam measurements.

6.1.4.3 If the foam breaks especially quickly, it is best to leave the fluid in the blender to avoid having to take time for transfer.

6.1.5 Protocol Variations:

6.1.5.1 The mixing speed, mixing duration, and rest duration may all be adjusted as needed to obtain useful data separation. Higher mixing speeds and longer mixing times are expected to generate more foam.

6.1.6 Most Appropriate Applications/Advantages:

6.1.6.1 A blender test is a useful test method because it is a very simple, quick to perform, and consumes minimal material.

6.1.6.2 It provides insight into how the fluid will behave in a higher shear environment. This lends itself to high throughput testing of many different formulations during R&D development, quality control testing during production, as well as condition monitoring in application.

6.1.7 Least Appropriate Applications/Limitations:

6.1.7.1 The primary limitation of blender testing is that it exposes the tested fluid to high shear stress for a short period of time. This is not representative of end-use application conditions where the fluid is exposed to moderate shear for prolonged periods of time.

6.1.7.2 The high shear stress created in the blender can be so aggressive that many different types of samples will show similarly high amounts of foam.

6.1.7.3 The shear stress applied during blending can reduce the molecular weight of polymeric foam-control agents.

6.1.7.4 Exposure to short-term, high shear stress conditions can hide performance differences among foam-control treatments that would be recognized easily under end-use conditions.

6.2 Shake Test:

6.2.1 *Concept*—A shake test is a foam collapse test performed by exposing the sample to a relatively low amount of shear in a short period of time.

6.2.2 *Apparatus*—A container is partially filled with the aqueous metalworking fluid dilution to be tested and sealed.

6.2.3 *Protocol Summary*—The container is then shaken for a set period and then allowed to rest on a level surface.

6.2.4 *Report*—During the rest period the foam volume or height (see **Note 4**) is recorded at specified time intervals. Lower foam volumes and faster foam break times are indications of better foam control.

6.2.5 *Protocol Variations*—There are many different variations of a shake test.

6.2.5.1 Graduated cylinders have a narrow surface area and, therefore, generally show a higher foam tendency than the same sample in a jar with a wider surface area. The benefit of jars is that they are convenient as they can be recycled, whereas graduated cylinders must be cleaned well.

6.2.5.2 Mechanical shake tests require additional equipment but allow for a more repeatable and reproducible result than hand-shake tests.

6.2.6 *Most Appropriate Applications/Advantages*—A shake test is a useful test method because it is very simple, quick to perform, and consumes minimal material. This lends itself to high throughput testing of many different formulations during R&D development, quality control testing during production, as well as condition monitoring in application.

6.2.7 *Least Appropriate Applications/Limitations*—The limitation of a shake test is that it only exposes the fluid to a low-shear environment for a short period of time. This is not representative of application conditions where the fluid is exposed to higher shear for prolonged periods of time. Consequently, samples may show a low foam tendency in a shake test but still cause foam issues in application.

6.3 Air Sparge Test:

6.3.1 *Concept*—An air sparge test is a short-duration foaming tendency test.

6.3.2 *Apparatus*—A cylinder is partially filled with the metalworking fluid dilution to be tested.

6.3.3 *Protocol Summary*—Air is sparged directly into the bottom of the bulk liquid for a few minutes. Air bubbles generate foam as they rise to the surface.

6.3.4 *Report*—The total foam volume or height is recorded at specified time intervals during the air sparge. Once the air pump is turned off, the foam collapse at the end of the test is also recorded over time. Smaller total volumes and faster foam collapse indicate decreased foaming tendency.

6.3.5 *Protocol Variations*—There are several variations of an air sparge test.

6.3.5.1 Adjusting the diffuser alters the size of the bubbles formed. Smaller pore sizes and smaller foam bubbles tend to create more stable foam.