Designation: E641 – 01 (Reapproved 2012)$^{\varepsilon 1}$

Standard Methods for Testing Hydraulic Spray Nozzles Used in Agriculture[1]

This standard is issued under the fixed designation E641; 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.

ε^1 NOTE—Editorial changes were made to the equation in subsection 6.3.4.5 in November 2012.

1. Scope

1.1 These methods cover procedures for testing hydraulic spray nozzles used in agriculture. The methods herein cover the following performance parameters: nozzle flow rate, nozzle spray angle, liquid distribution, spray droplet size, and nozzle wearability.

1.2 These methods are applicable to hydraulic spray nozzles which produce the following spray patterns: flat-fan, hollow cone, and full cone.

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 the safety concerns 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. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 The types of hydraulic spray nozzles considered are categorized according to spray characteristics, as follows:

2.1.1.1 *flat-fan "tapered edge" type spray nozzle*—this nozzle provides a range of atomization sizes throughout the pattern area. Its edges are tapered to permit the overlapping of spray patterns from adjacent nozzles, thereby providing relatively uniform overall distribution. These nozzles are popular on field-type crop sprayers where uniform coverage is desired across the swath.

2.1.1.2 *flat fan "even edge" type spray nozzle*—this nozzle provides relatively uniform atomization size as compared to the "tapered edge" type nozzle and uniform distribution throughout the spray pattern. There is no requirement for overlap of adjacent spray patterns when using this nozzle. It is used primarily to spray uniform strips or bands in fields.

2.1.1.3 *flooding or deflector-fan type spray nozzle*—this nozzle produces a low impact spray with a wide-angle flat pattern having uniform distribution when low pressures are used. It is used primarily on field-type sprayers when broad coverage at lower pressures is desired.

2.1.1.4 *hollow cone and full cone nozzle*—the hollow cone nozzle normally provides uniform distribution throughout a hollow cone pattern area. The full cone nozzle, provides uniform distribution throughout its full cone pattern. Both types are used extensively for spraying of fruits and vegetables, some row crops with pesticides, and aerial applications.

3. Significance and Use

3.1 The purpose of these methods is to provide uniform testing procedures for evaluating the performance criteria of hydraulic spray nozzles used for agricultural purposes.

3.2 The procedures set forth in these methods are for spray nozzles of the hydraulic energy type in which the spray material is forced through an orifice under pressure, providing fluid break-up into droplets.

3.3 Droplet producing nozzles that operate by means other than hydraulic energy are not applicable to these methods.

4. Apparatus

4.1 This section covers equipment used in testing hydraulic spray nozzles. The equipment and apparatus listed are sufficient for use in all methods described herein.

4.2 Fundamental equipment common to all of the test methods are as follows:

4.2.1 *Water Reservoir or Retaining Vessel*—A water reservoir or vessel sufficiently large to provide smooth continuous flow to the nozzle(s) throughout the duration of a particular test.

4.2.2 *Pump or Source of Water Pressure*—A pump or source of water pressure sufficient to maintain the required test pressure with less than ±2 % deviation from the nominal pressure.

4.2.3 *Pressure Gage:*

[1] These methods are under the jurisdiction of ASTM Committee E35 on Pesticides, Antimicrobials, and Alternative Control Agents and are the direct responsibility of Subcommittee E35.22 on Pesticide Formulations and Delivery Systems.

Current edition approved Oct. 1, 2012. Published November 2012. Originally approved in 1978. Last previous edition approved in 20016 as E641 – 01 (2006). DOI: 10.1520/E0641-01R12.

4.2.3.1 A pressure gage with an accuracy of ±2 % at the actual working pressure. It should have a maximum pressure reading on the dial face such that the test pressure can be as near the midrange of the gage as possible.

4.2.3.2 The pressure gage should be calibrated prior to use at each of the required test pressures by using a Certified Dead Weight Gage calibrator or a suitable manometer capable of gage calibration.

4.2.4 *Pressure Regulator,*

4.2.5 *Control Valves,*

4.2.6 *Inline Strainer,*

4.2.7 *Piping,*

4.2.8 *Union Tees,*

4.2.9 *Union Elbows.*

4.3 General equipment and arrangement schematics used in testing each of the performance criteria are as follows.

4.3.1 *Discharge Rate:*

4.3.1.1 *Apparatus Schematic*—See Fig. 1.

4.3.1.2 *Cylinders,* Graduated, sized to meet specific test requirement.

4.3.1.3 *Stop Watch,* having 0.2-s resolution or better.

4.3.1.4 *Collecting Vessel,* glass, metal or plastic, sized to meet test requirements.

4.3.1.5 *Laboratory Beakers,*

4.3.1.6 *Flowmeter,* Electronic or manual with accuracy of ±3 % of scale

4.3.1.7 *Balance,* top loading with sensitivity of ±0.01 g or better accuracy of 0.1 g or better.

4.3.2 *Spray angle:*

4.3.2.1 *Apparatus Schematic*—See Fig. 2.

4.3.2.2 *Spray Pattern Distribution Testing Table.*

4.3.2.3 *Spray Protractor,* having a minimum arm length of 300-mm (12-in.).

4.3.3 *Distribution:*

4.3.3.1 *Apparatus Schematic*—See Fig. 3 and Fig. 4.

4.3.3.2 *Spray Pattern Distribution Testing Table.*

4.3.3.3 *Spray Pattern Distribution Testing Racks, Troughs, and Beakers.*

4.3.3.4 *Balance,* as in 4.3.1.7.

4.3.3.5 *Stop Watch,* as in 4.3.1.3.

4.3.4 *Particle Size*—Since there is no agreement on methods of sampling and measurement, this section is omitted at this time. (Note the section on reporting of measurements, 6.5.)

4.3.5 *Wearability:*

4.3.5.1 *Apparatus Schematic*—See Fig. 5.

4.3.5.2 *Pressure Tank,* with agitator and air regulator.

4.3.5.3 *Wear Media.*

4.3.5.4 *Imhoff Settling Cone,* 1000-ml.

4.3.5.5 *Spray Pattern Distribution Testing Table.*

4.3.5.6 *Spray Pattern Distribution Testing Racks, Troughs, and Beakers.*

4.3.5.7 *Collection Vessel,* as in 4.3.1.4.

4.3.5.8 *Balance,* as in 4.3.1.7.

4.3.5.9 *Stop Watch,* as in 4.3.1.3.

4.3.5.10 *Cylinder,* as in 4.3.1.2.

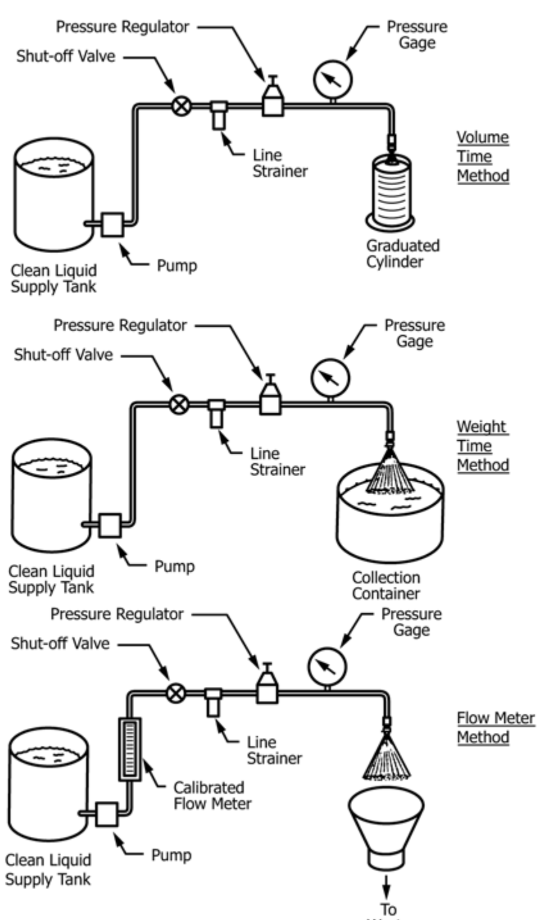

FIG. 1 Discharge Rate Test Equipment

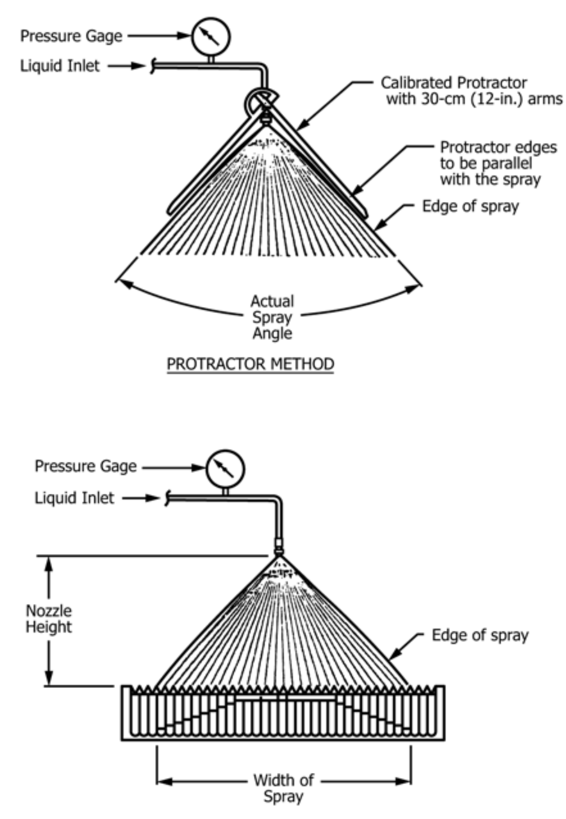

FIG. 2 Spray Angle Test Equipment

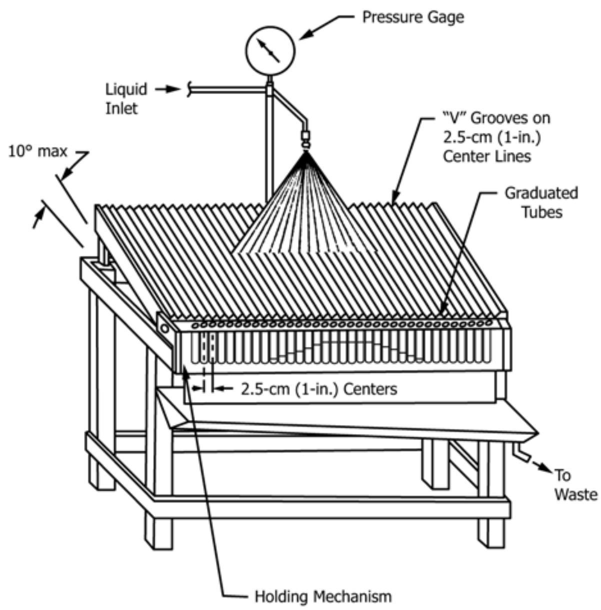

FIG. 3 Distribution Table

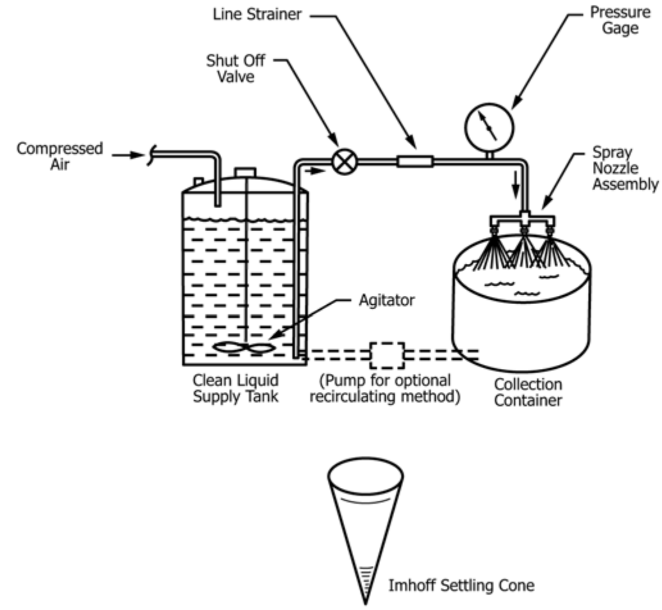

FIG. 5 Wearability Test Equipment

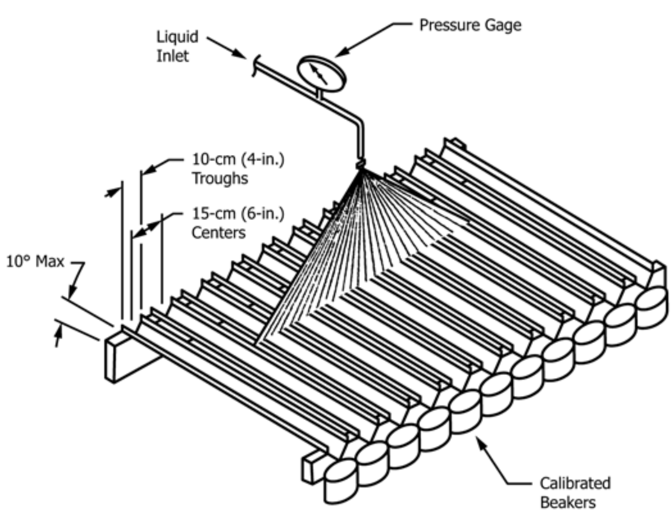

FIG. 4 Distribution Rack

4.3.5.11 *Flowmeter,* as in 4.3.1.6.

5. Spray Medium

5.1 It has been accepted practice to use clean, clear water as a standard. However, testing procedures do not preclude using these methods for other liquids.

5.2 Unless otherwise indicated, references to water shall be understood to mean clean, clear, filtered water at a temperature of 20 to 25°C (68 to 70°F).

6. Procedure

6.1 *Pressure Adjustment:*

6.1.1 *Pump Method:*

6.1.1.1 Add the spray media to the system.

6.1.1.2 With the recirculation valve open and the spray valve closed, turn on the spray pump.

6.1.1.3 Open the spray valve and slowly close the recirculation valve until the desired spray pressure is reached.

6.1.2 *Air Pressure Method:*

6.1.2.1 Add the spray media to the system.

6.1.2.2 With both the spray valve and pressure regulator closed, apply air pressure to the system.

6.1.2.3 Open the spray valve and slowly open the pressure regulator until the desired spray pressure is obtained.

6.2 *Discharge Rate:*

6.2.1 The discharge rate of a nozzle is normally denoted in volume-time units such as litres per minute, litres per second, or gallons per minute.

6.2.2 The discharge rate can be determined by a method such as an actual volume-time measurement, an actual weight-time measurement, or a volume-time measurement observed directly from an accurately calibrated flow meter. The discharge rate of the nozzle may determine what method of measurement is practical. (See Fig. 1.)

6.2.3 *Volume-Time Measurement Method:*

6.2.3.1 Adjust spray pressure to desired setting.

6.2.3.2 Pass water through the nozzle and collect it in a clean, dry, graduated cylinder for an interval of at least 1 min, as measured by a stop watch. The nozzle discharge during the time interval should fill at least 75 % of the cylinder graduated volume.

6.2.3.3 Read the amount of water collected directly from the graduated cylinder to the nearest units denoted, thereby providing the volume-time discharge rate.

6.2.3.4 Repeat this procedure three separate times and use an average of the three observations as the measured discharge rate.

6.2.3.5 *Report*—Nozzle type and size, test pressure, spray time, average discharge rate, graduated cylinder capacity and lowest unit of measure, and spray media.

6.2.4 *Weight-Time Method:*

6.2.4.1 Establish the tare weight of a collection vessel.

6.2.4.2 Adjust spray pressure to desired setting.

6.2.4.3 Spray water into the collection vessel for an interval of at least 1 min, as timed by a stop watch.

6.2.4.4 Establish the net weight of the discharged water by reweighing the collection vessel to the nearest 0.1 g. The result is a weight-time discharge rate that is mathematically converted to the volume-time values normally used to denote discharge rate.

$$\frac{\mathrm{L}}{\mathrm{min}} = \frac{\mathrm{kg}}{\mathrm{min}} \times 1$$

$$\left(\frac{\mathrm{gal}}{\mathrm{min}} = \frac{\mathrm{lb}}{\mathrm{min}} \times \frac{1}{8.32}\right)$$

6.2.4.5 Repeat this procedure three separate times and use an average of the three observations as the measured discharge rate.

6.2.4.6 *Report*—Nozzle type and size, test pressure, spray time, average discharge rate, net weight, net weight of discharge, and spray media.

6.2.5 *Flow Meter Method:*

6.2.5.1 Calibrate the flowmeter by an actual volume-time procedure as described in 6.2.3. Exercise caution when using flowmeters since water temperature, build up of mineral deposits and age of meters can seriously alter accuracy.

6.2.5.2 Pass water directly through the flow meter at the desired test pressure to provide "direct" discharge rate readings. An average of at least two meter reading should be used for determining the discharge rate. One reading should be taken by slowly increasing the pressure up to the desired test pressure. A second reading should be taken by increasing the pressure beyond the desired test pressure and slowly lowering the pressure back to the desired pressure.

6.2.5.3 *Report*—Nozzle type and size, test pressure, spray time, average discharge rate, type and scale of flowmeter, and spray media.

6.3 *Spray Angle:*

6.3.1 The spray angle of a nozzle is normally denoted in terms of degrees and is a measure of the angular segment formed by the nozzle orifice and the outermost edges of its generated spray.

6.3.2 The spray angle of the four different types of spray nozzles can be determined by an angular measure using a calibrated protractor or on a spray distribution testing table by measuring the effective pattern width and using the spray height to calculate the angle. The size of the nozzle may determine which method of measuring is practical. (See Fig. 2.)

6.3.3 *Angular Measurement:*

6.3.3.1 Set the desired spray pressure, as determined by the specific spray application, according to the method given in 6.1.

6.3.3.2 Pass water through the nozzle and position the calibrated protractor above the spray.

6.3.3.3 Open the protractor arms wider than the spray pattern to be measured and position the vertex of the angle as close to the point of spray discharge as possible. Then slowly narrow the protractor's arms to where they become parallel for the longest distance with the edges of the spray pattern.

6.3.3.4 Read the relative spray angle directly from the protractor.

6.3.3.5 Repeat this testing procedure three separate times and use an average of the three observations as the measured spray angle.

6.3.4 *Width-of-Coverage Method:*

6.3.4.1 Mount the nozzle at a predetermined distance above the spray distribution testing table.

6.3.4.2 Set the desired spray pressure as determined by the specific spray application, according to the method given in 6.1.

6.3.4.3 Pass water through the nozzle for an interval of time sufficient to define spray pattern. Allow the water to run down the "V" grooves on the table and collect in the graduated cylinders positioned under the grooves.

6.3.4.4 Determine the actual width of the spray pattern by observing the cylinders outermost from the spray center retaining a sufficient amount of water to define the spray width.

6.3.4.5 Obtain the effective spray angle by using the following trigometric calculation:

$$\left(2 \times \tan^{-1}\left(\frac{1}{2}\, width/height\right)\right)$$

6.4 *Spray Volume Distribution:*

6.4.1 The relative volume distribution of a nozzle is determined by dividing the width-of-spray pattern into equal segments and comparing the amount of water collected in each segment with those adjacent to it. The distribution is normally represented in volumetric units such as milliliters per minute, litres per minute, gallons per minute, or relative volumetric units.

6.4.2 The volume distribution of the four different types of spray nozzles may be determined by an actual volume-time measurement or a weight-time measurement. The size and type of nozzle may determine which method of measurement is practical. The majority of the flat-fan type nozzles and the cone-type nozzles would encourage the use of the volume-time method. Large capacity flat-fan type nozzles and the flooding type nozzles would favor the weight-time method (see Fig. 3 and Fig. 4).

6.4.3 *Volume-Time Method:*

6.4.3.1 Mount the nozzle at a predetermined distance above the spray distribution testing table.

6.4.3.2 Set the desired spray pressure according to the method given in 6.1.

6.4.3.3 Pass water through the nozzle for a short period of time to allow the troughs to become wetted and provide uniform dripping from the valleys of the groves. To ensure that no water enters the graduated tubes cylinders located at the end of the troughs during this process, a graduated tube holding mechanism which allows the tubes cylinders to be quickly swung in and out of the spray's run-off is used.

6.4.3.4 Collect the water in the graduated tubes for a given interval of time.

6.4.3.5 In some cases it may be impractical to swivel the tube holding mechanism. Under such circumstances it is desirable to use a shutter-type procedure in conducting the distribution test. Set the test pressure while diverting the spray away from the collection device until the pressure has stabilized. Then quickly release the deflection device and collect the spray for the appropriate interval. Take care using this method so as not to get extraneous readings caused by the movement of the shuttering device.

6.4.3.6 Read the amount of water collected directly from the graduated tubes cylinders to the nearest unit denoted, thereby providing the volume-time discharge for equal increments within the spray.

6.4.3.7 Repeat the procedure and use an average of the two observations as the result.

6.4.3.8 *Report*—Nozzle type and size, test pressure, spray time, average discharge rate for each segment, graduated tube capacity & lowest unit of measure, and spray media.

6.4.4 *Weight-Time Method:*

6.4.4.1 Mount the nozzle at a predetermined distance above the spray distribution testing table.

6.4.4.2 Set the desired spray pressure according to the method given in 6.1.

6.4.4.3 Establish the tare weight of all collection vessels.

6.4.4.4 Spray water through the nozzle for a short period of time to allow the troughs to become wetted and provide uniform dripping from the valleys of the groves. To ensure that no water enters the collection vessels during this process, a shuttering device as described in 6.4.3.5 is normally used.

6.4.4.5 Collect the water in the collection vessels for a given interval of time.

6.4.4.6 Establish the net weight of the discharged water for each segment by reweighing each collection vessel to the nearest 0.1 gram. The result is a weight-time discharge per segment that can be mathematically converted to a volume-time value if the specific gravity of the spray liquid is known.

6.4.4.7 Repeat the procedure and use an average of the two observations as the result.

6.4.4.8 *Report*—Nozzle type and size, test pressure, spray time, average discharge rate for each segment, net weight of discharge for each segment, and spray media.

6.5 *Particle Size Distribution Reporting:*

6.5.1 Refer to standards that pertain to measuring and reporting droplet size distributions which are under the jurisdiction of ASTM Subcommittee E29.04 "Liquid Particle Measurement". These standards currently include:

E799 Practice for Determining Data Criteria and Processing for Liquid Drop Size Analysis

E1088 Definitions of Terms Relating to Atomizing Devices

E1296 Standard Terminology Relating to Liquid Particle statistics

E1260 Test Method for Determining Liquid Drop Size Characteristics in a Spray Using Optical Non-Imaging Light-Scattering Instruments

E1458 Test Method for Calibration Verification of Laser Diffraction Particle Sizing Instruments Using Photomask Reticles

E1620 Standard Terminology Relating to Liquid Particles and Atomization

6.6 *Wearability:*

6.6.1 The tolerable deviations in nozzle performance parameters vary considerably from one application to another. The useful wear life of a nozzle is established when any one of its spray characteristics no longer meets performance requirements prescribed for a given application.

6.6.2 Test the wear characteristics of a nozzle using an apparatus similar to that shown in Fig. 5.

6.6.3 *Specific Test Method:*

6.6.3.1 Use the methods described in 6.2, 6.3, and 6.4 to measure the discharge rate, spray angle, and liquid spray volume distribution of each nozzle to be evaluated in the wear test and record the results. A minimum of three nozzles should be evaluated in order to allow for simultaneous testing and data averaging.

6.6.3.2 Prepare a spray mixture to be tested by filling the supply tank with a specified amount of water and adding the test material.

6.6.3.3 Install the pre-tested nozzles to be worn in the system and adjust the pressure to the desired test pressure according to the method given in 6.1.

6.6.3.4 Spray the fluid mixture to be tested through the nozzle.

6.6.3.5 At periodic intervals during the wear test, remove the nozzle from the system, measure the discharge rate, spray angle, and distribution as previously described, and record observations along with the time interval of the tests.

6.6.3.6 Repeat procedure 6.6.3.5 until the prescribed limits for useful life are reached for the particular fluid mixture or application.

6.6.3.7 Conduct tests on a sufficient number of nozzles to give a statistical average indicative of the wear life of the particular type of nozzle.

6.6.3.8 *Report*—Nozzle type and size, test pressure, spray media, time to failure, initial and final: discharge rate, spray angle, and distribution.

6.6.4 *Common Media Method:*

6.6.4.1 The wear life of a nozzle for a particular application is determined using a common spray media. This wear life can then be used as a reference for determining the expected wear life of other nozzles with regards to a specific spray media using various pressures. This method also allows wear data to be generated at an "accelerated" rate when compared to performing the Specific Media Method.

6.6.4.2 Measure the discharge rate, spray angle, and liquid spray volume distribution of each nozzle to be tested using the methods described in 6.2, 6.3, and 6.4 and record the test results. A minimum of three nozzles should be evaluated in order to allow for simultaneous testing and data averaging.

6.6.4.3 Prepare a slurry (20 % solids content is normal) by filling the supply tank with a specified amount of liquid and wear media (such as a uniform sieve size quartz).

6.6.4.4 Install the pre tested nozzles to be worn in the system and adjust the spray pressure to the desired test pressure according to the method given in 6.1.

6.6.4.5 An agitation system in the tank is essential and shall be in operation at all times to assure uniform suspension of the slurry mixture. Before, and periodically throughout the wear test, obtain sedimentation readings of the slurry solution by collecting the discharge from one of the nozzles in a 100 ml Imhoff cone. Make a mixture ratio reading after the slurry has had 15 min to settle. The sedimentation level shall meet predetermined specifications that indicate the liquid and wear media suspension ratio is correct.

6.6.4.6 Spray the slurry solution through multiple nozzle assembly.

6.6.4.7 At predetermined intervals throughout the duration of the wear test, remove the nozzles from the system, measure the discharge rate, spray angle, and spray volume distribution using the same spray media used for the Specific Media Method. Record observations along with the time interval of the test.

6.6.4.8 Repeat procedure 6.6.4.7 until the nozzles' performance deteriorates to the previously determined wear life established by the Specific Media Method.

6.6.4.9 At the point of failure, (e.g predetermined percent of original flow) determine the discharge rate, spray angle, and spray volume distribution of each nozzle using the common media slurry and common media spray system. In order for these test to be performed, the spray nozzle assembly on the common media system will have to be reduced to a single nozzle.

6.6.4.10 *Report*—Nozzle type and size, test pressure, wear media & load, time to failure, final discharge rate, spray angle, and spray volume distribution.

6.6.4.11 The relationship of the wear life of the a nozzle on the common media tested to that of a fluid used in the Specific Media Method enables wear life evaluations to be more independent and allows comparison of one nozzle to another and one material to another.