



# Standard Practice for Coagulation-Flocculation Jar Test of Water<sup>1</sup>

This standard is issued under the fixed designation D2035; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers a general procedure for the evaluation of a treatment to reduce dissolved, suspended, colloidal, and nonsettleable matter from water by chemical coagulation-flocculation, followed by gravity settling. The procedure may be used to evaluate color, turbidity, and hardness reduction.

1.2 The practice provides a systematic evaluation of the variables normally encountered in the coagulation-flocculation process.

1.3 The values stated in SI units are to be regarded as standard.

1.4 *This standard does not purport to address 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:<sup>2</sup>

D1129 Terminology Relating to Water

D1193 Specification for Reagent Water

D1293 Test Methods for pH of Water

D3370 Practices for Sampling Water from Closed Conduits

D6855 Test Method for Determination of Turbidity Below 5 NTU in Static Mode

D7315 Test Method for Determination of Turbidity Above 1 Turbidity Unit (TU) in Static Mode

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology D1129.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.03 on Sampling Water and Water-Formed Deposits, Analysis of Water for Power Generation and Process Use, On-Line Water Analysis, and Surveillance of Water.

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

## 4. Summary of Practice

4.1 The coagulation-flocculation test is carried out to determine the chemicals, dosages, and conditions required to achieve optimum results. The primary variables to be investigated using the recommended practice include, but are not limited to:

4.1.1 Chemical additives,

4.1.2 pH,

4.1.3 Temperature, and

4.1.4 Order of addition and mixing conditions.

## 5. Significance and Use

5.1 This practice permits the evaluation of various coagulants and coagulant aids used in the treatment of water and waste water for the same water and the same experimental conditions.

5.2 The effects of concentration of the coagulants and coagulant aids and their order of addition can also be evaluated by this practice.

## 6. Interferences

6.1 There are some possible interferences that may make the determination of optimum jar test conditions difficult. These include the following:

6.1.1 *Temperature Change (During Test)*—Thermal or convection currents may occur, interfering with the settling of coagulated particles. This can be prevented by temperature control.

6.1.2 *Gas Release (During Test)*—Flotation of coagulated floc may occur due to gas bubble formation caused by mechanical agitator, temperature increase or chemical reaction.

6.1.3 *Testing-Period*—Biological activity or other factors may alter the coagulation characteristics of water upon prolonged standing. For this reason the period between sampling and testing should be kept to a minimum, with the time being recorded.

## 7. Apparatus

7.1 *Multiple Stirrer*—A multiposition stirrer with continuous speed variation from about 20 to 150 rpm should be used. The stirring paddles should be of light gage corrosion-resistant material all of the same configuration and size. An illuminated base is useful to observe the floc formation. Precautionary

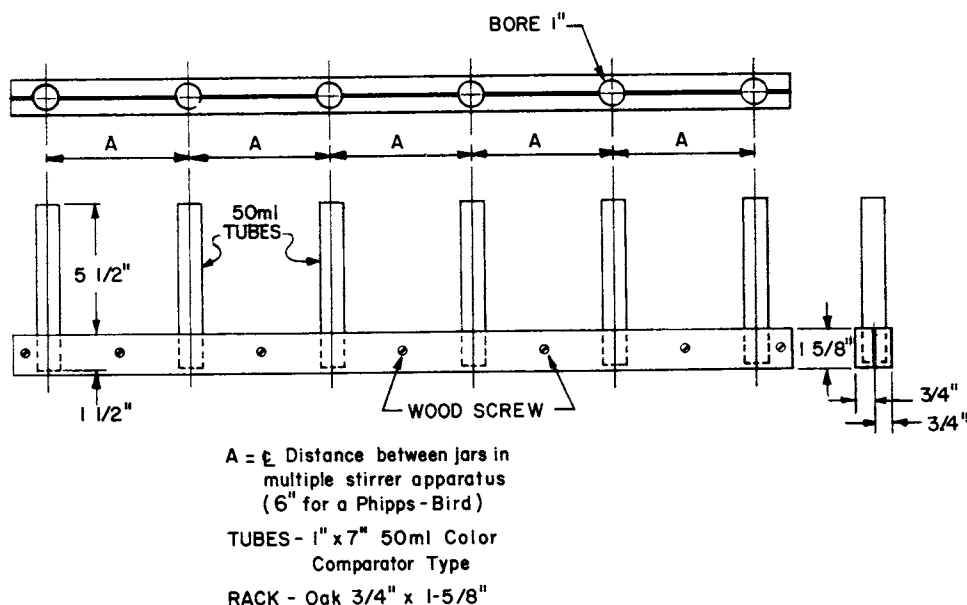


FIG. 1 Reagent Rack for Multiple Stirrer Jar Test Apparatus

measures should be taken to avoid heat being imparted by the illumination system which may counteract normal settling.

7.2 *Jars (or Beakers)*, all of the same size and shape; 1500-mL Griffin beakers may be used (1000-mL recommended minimum size).

7.3 *Reagent Racks*— A means of introducing each test solution to all jars simultaneously. There should be at least one rack for each test solution or suspension. The racks should be similar to that shown in Fig. 1.

## 8. Reagents

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>3</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.2 *Purity of Water*—Reference to water that is used for reagent preparation, rinsing or dilution shall be understood to mean water that conforms to the quantitative specifications of Type IV reagent water of Specification D1193.

8.3 The following chemicals and additives are typical of those used for test solutions and suspensions. The latter, with the exception of coagulant aids, may be prepared daily by mixing chemicals with water to a concentration of 10 ( $\pm 0.1$ ) g/L (1.0 mL of test solution or suspension when added to 1 L of sample is equivalent to 10 mg/L):

- Prime Coagulants
  - Alum [ $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ ]
  - Ferric sulfate [ $\text{Fe}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$ ]
  - Ferric chloride ( $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ )
  - Ferrous sulfate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ )
  - Magnesium carbonate ( $\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$ )
  - Sodium aluminate ( $\text{NaAlO}_2$ )
- Coagulant Aids
  - Activated silica
  - Anionic (polyelectrolyte)
  - Cationic (polyelectrolyte)
  - Nonionic Polymer
- Oxidizing Agents
  - Chlorine ( $\text{Cl}_2$ )
  - Chlorine dioxide ( $\text{ClO}_2$ )
  - Potassium permanganate ( $\text{KMnO}_4$ )
  - Calcium hypochlorite [ $\text{CaCl}(\text{ClO}) \cdot 4\text{H}_2\text{O}$ ]
  - Sodium hypochlorite ( $\text{NaClO}$ )
- Alkalis
  - Calcium carbonate ( $\text{CaCO}_3$ )
  - Dolomitic lime
  - (58 %  $\text{CaO}$ , 40 %  $\text{MgO}$ )
  - Lime, hydrated [ $\text{Ca}(\text{OH})_2$ ]
  - Magnesium oxide ( $\text{MgO}$ )
  - Sodium carbonate ( $\text{Na}_2\text{CO}_3$ )
  - Sodium hydroxide ( $\text{NaOH}$ )
- Weighting Agents
  - Bentonite
  - Kaolin
  - Other clays and minerals
- Miscellaneous
  - Activated carbon (powdered)

8.4 *Coagulant Aids*— There are numerous commercially available coagulant aids or polyelectrolytes. All polyelectrolytes are classified anionic, cationic or nonionic, depending upon their composition. These aids may have the ability to produce large, tough, easily-settled floc when used alone or in conjunction with inorganic coagulants. A small dosage (under 1 mg/L) may permit a reduction in the dosage of, or complete elimination of, the coagulant. In the latter case, the polyelectrolyte would be considered the prime coagulant rather than a coagulant aid. Aids come in powdered and liquid form. Powdered aids should be prepared as 0.1 % solutions with appropriate aliquots to provide proper dosage. Always add

<sup>3</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

powdered aids to the dissolving water rather than the reverse, and add slowly to the shoulder of a vortex created by stirring. If a vortex is not formed, the dry powder will merely collect on the surface of the water in gummy masses and become very difficult to dissolve. Dissolving time may vary from several minutes to several hours. Suggested manufacturers' procedures for wetting, dissolving, and storing should be followed when available. Liquid forms can be readily prepared to the above strength without difficulty.<sup>4</sup>

## 9. Sampling

9.1 Collect the water sample under test in accordance with the applicable Practices **D3370**.

## 10. Procedure

10.1 Measure equal volumes (1000 mL) of sample into each of the jars or 1500-mL Griffin beakers. As many sample portions may be used as there are positions on the multiple stirrer. Locate beakers so that the paddles are off-center, but clear the beaker wall by about 6.4 mm ( $\frac{1}{4}$  in.). Record the sample temperature at the start of the test.

10.2 Load the test chemicals in the reagent racks. Use one rack for each series of chemical additions. Make up each tube in the rack to a final volume of 10 mL, with water, before using. There may be a situation where a larger volume of reagent will be required. Should this condition prevail, fill all tubes with water to a volume equal to the largest volume of reagent in the reagent rack. When adding slurries, it may be necessary to shake the rack to produce a swirling motion just prior to transfer.

10.3 Start the multiple stirrer operating at the "flash mix" speed of approximately 120 rpm. Add the test solution or suspensions, at predetermined dosage levels and sequence. Flash mix for approximately 1 min after the additions of chemicals. Record the flash mix time and speed (rpm).

10.4 Reduce the speed as necessary to the minimum required to keep floc particles uniformly suspended throughout

the "slow mix" period. Slow mix for 20 min. Record the time for the first visible floc formation. Every 5 min (during the slow mix period), record relative floc size and mixer speed (rpm). If coagulant aids are used, mixing speed is critical because excessive stirring tends to break up early floc formation and may redisperse the aid.

10.5 After the slow mix period, withdraw the paddles and observe settling of floc particles. Record the time required for the bulk of the particles to settle. In most cases this time will be that required for the particles to settle to the bottom of the beaker; however, in some cases there may be interfering convection currents. If so, the recorded settling time should be that at which the unsettled or residual particles appear to be moving equally upward and downward.

10.6 After 15 min of settling, record the appearance of floc on the beaker bottom. Record the sample temperature. By means of a pipet or siphon, withdraw an adequate sample volume of supernatant liquor from the jar at a point one half of the depth of the sample, to conduct color,<sup>5</sup> turbidity, pH and other required analyses, (**Note 1**) determined in accordance with Test Methods **D6855** or **D7315** (for turbidity) and **D1293** (for pH). A suggested form for recording results is appended (see **Fig. 2**).

**NOTE 1**—Tests for residual chemicals should be included, for example, alum; residual  $\text{Al}_2\text{O}_3$ ; copperas; residual  $\text{Fe}_2\text{O}_3$ ; etc.

10.7 Repeat steps **10.1–10.6** until all pertinent variables have been evaluated.

10.8 The times given in **10.3**, **10.4**, and **10.6** are only suggestions.

## 11. Reproducibility

11.1 It is recognized that reproducibility of results is important. To demonstrate reproducibility, the so-called 3 and 3 procedure is suggested. In this procedure, duplicate sets of 3 jars each are treated simultaneously with the same chemical dosages in jars 1 and 4, 2 and 5, and 3 and 6.

## 12. Keywords

12.1 coagulation; flocculation; jar tests

<sup>4</sup> A periodically updated "Report on Coagulant Aids for Water Treatment" is published by the Environmental Protection Agency Office of Water Supply, Cincinnati, Ohio 45268, listing coagulant aids that may be used in water treatment without adverse physiological effects on those using the water, based on information submitted by the manufacturers or distributors, or both.

<sup>5</sup> For the color determination, reference is made to *Standard Methods for the Examination of Water and Waste Water*, Fourteenth edition, American Public Health Association, Inc., New York, NY, 1975, pp. 64–71.

|                |             |                   |                      |  |  |  |
|----------------|-------------|-------------------|----------------------|--|--|--|
| Sample _____   | pH _____    | Turbidity _____   | Date _____           |  |  |  |
| Location _____ | Color _____ | Temperature _____ | Sample Size _____ ml |  |  |  |

|                                  | JAR NUMBER |   |   |   |   |   |
|----------------------------------|------------|---|---|---|---|---|
|                                  | 1          | 2 | 3 | 4 | 5 | 6 |
| Chemicals, mg/litre ( <i>a</i> ) |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
|                                  |            |   |   |   |   |   |
| Flash Mix Speed, rpm             |            |   |   |   |   |   |
| Flash Mix Time, min              |            |   |   |   |   |   |
| Slow Mix Speed, rpm              |            |   |   |   |   |   |
| Slow Mix Time, min               |            |   |   |   |   |   |
| Temperature, °F                  |            |   |   |   |   |   |
| Time First Floc, min             |            |   |   |   |   |   |
| Size Floc                        |            |   |   |   |   |   |
| Settling rate                    |            |   |   |   |   |   |
| Turbidity                        |            |   |   |   |   |   |
| Color                            |            |   |   |   |   |   |
| pH                               |            |   |   |   |   |   |

(*a*) Indicate order of addition of chemicals.

**FIG. 2 Jar Test Data**

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