Designation: D6482 – 06 (Reapproved 2016)

Standard Test Method for Determination of Cooling Characteristics of Aqueous Polymer Quenchants by Cooling Curve Analysis with Agitation (Tensi Method)[1]

This standard is issued under the fixed designation D6482; 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 covers the equipment and the procedure for evaluation of quenching characteristics of a quenching fluid by cooling rate determination.

1.2 This test method is designed to evaluate quenching fluids with agitation, using the Tensi agitation apparatus.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

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]

D6200 Test Method for Determination of Cooling Characteristics of Quench Oils by Cooling Curve Analysis

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

2.2 *SAE Standard:*[3]

AMS 5665 Nickel Alloy Corrosion and Heat Resistant Bars, Forgings and Rings

2.3 *Japanese Industrial Standards:*[4]

JIS K 2242 Heat Treating Oil

JIS K 6753 Di-2-ethylhexyl Phthalate

2.4 *Wolfson Engineering Group:*[5]

Wolfson Engineering Group Specification Laboratory Tests for Assessing the Cooling Curve of Industrial Quenching Media

2.5 *ASTM Adjuncts:*[6]

ADJD6300 D2PP, Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *aqueous polymer quenchant*—an aqueous solution containing a water soluble polymer; typically including poly(alkylene glycol), poly(ethyl oxazoline), poly(solium acrylate) and poly(vinyl pyrrolidone) (**1, 2**) .[7] The quenchant solution also typically contains additives for corrosion and foam control, if needed. Quench severity of aqueous polymer quenchants is dependent on concentration and molecular weight of the specific polymer being evaluated, quenchant temperature, and agitation rate as shown in Figs. 1-3, respectively.

3.1.2 *cooling curve*—a graphical representation of the cooling time (t)-temperature (T) response of the probe (see 7.3). An example is illustrated in Fig. 4A.

3.1.3 *cooling curve analysis*—the process of quantifying the cooling characteristics of a quenchant based on the temperature versus time profile obtained by cooling a preheated metal probe assembly (see Fig. 5) under standard conditions (**1, 3, 4**).

3.1.4 *cooling rate curve*—obtained by calculating the first derivative (dT/dt) of the cooling time-temperature curve. An example is illustrated in Fig. 4B.

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.L0.06 on Non-Lubricating Process Fluids.

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[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] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

[4] Available from Japanese Standards Organization (JSA), 4-1-24 Akasaka Minato-Ku, Tokyo, 107-8440, Japan, http://www.jsa.or.jp.

[5] Wolfson Heat Treatment Centre, Federation House, Vyse St., Birmingham, B18 6LT, UK, http://www.sea.org.uk/whtc.

[6] No longer available from ASTM International Headquarters.

[7] The boldface numbers in parentheses refer to the list of references at the end of this standard.

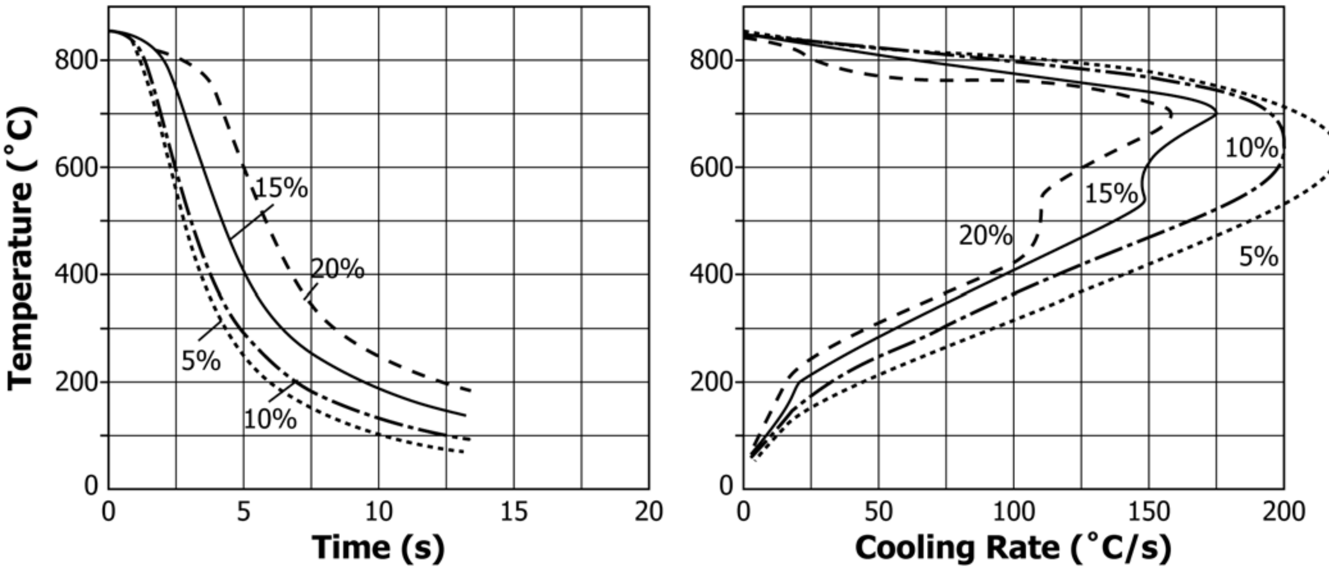


FIG. 1 Illustration of the Effect of Quenchant Concentration on Cooling Curve Performance for Poly(Alkylene Glycol) Quenchant at 30°C and 0.5 m/s

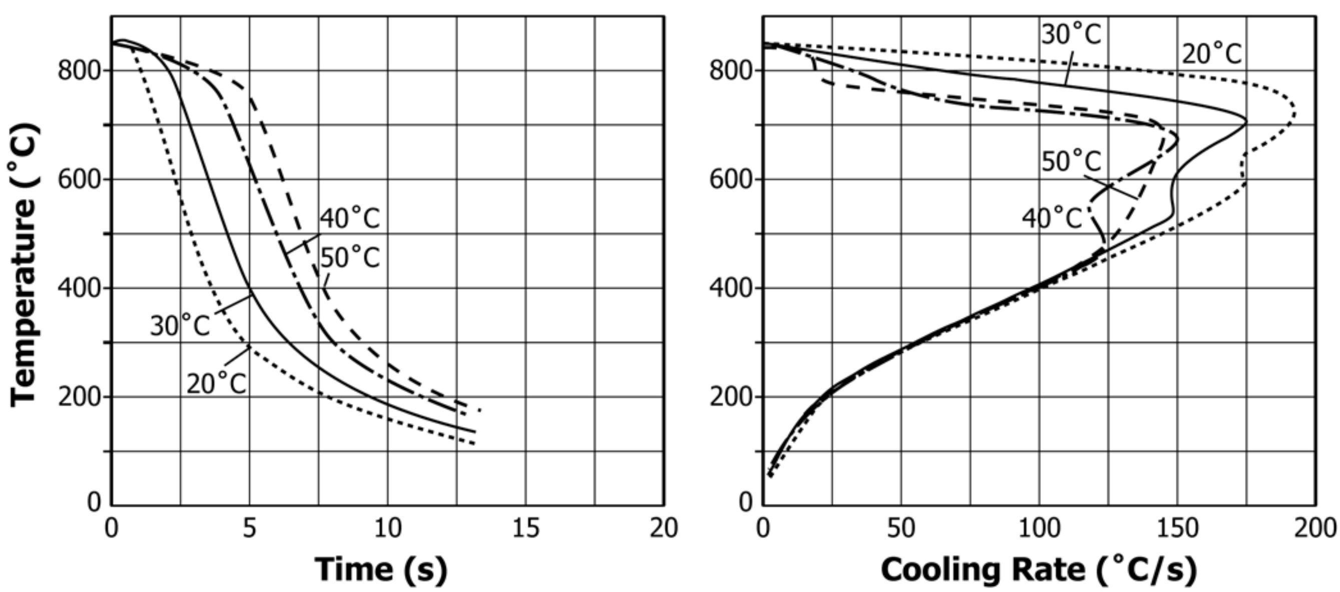


FIG. 2 Illustration of the Effect of Bath Temperature Variation on Cooling Curve Performance for 15 % Aqueous Solution of Poly (Alkylene Glycol) Quenchant at 0.5 m/s

3.1.5 *quench severity*—the ability of a quenching medium to extract heat from a hot metal (**5**).

3.1.6 *quenchant*—any medium, liquid or gas that may be used to mediate heat transfer during the cooling of hot metal.

4. Summary of Test Method

4.1 The nickel alloy probe assembly's cooling time versus temperature is determined after placing the assembly in a furnace and heating to 850 °C (1562 °F) and then quenching into an aqueous polymer quenchant solution. The temperature inside the probe assembly and the cooling times are recorded at selected time intervals to establish a cooling temperature versus time curve. The resulting cooling curve may be used to evaluate quench severity (see Note 1).

NOTE 1—For production testing, the furnace temperature of 815 °C to 857 °C (1500 °F to 1575 °F) may be used.

5. Significance and Use

5.1 This test method provides a cooling time versus temperature pathway that is directly proportional to physical properties such as the hardness obtainable upon quenching of a metal. The results obtained by this test method may be used as a guide in quenchant selection or comparison of quench severities of different quenchants, new or used.

6. Interferences

6.1 The presence of contaminants, such as oil, salt, metalworking fluids, forging lubricants, and polymer degradation,

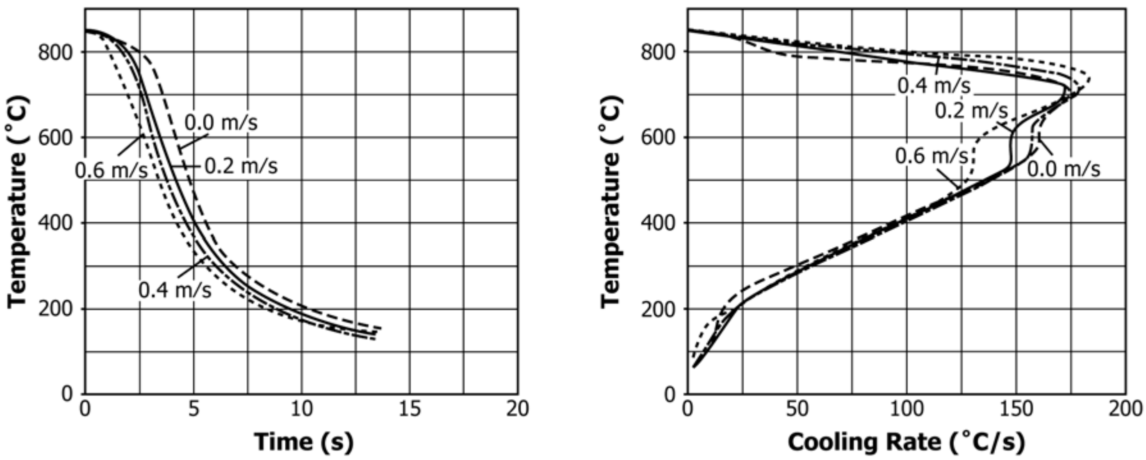
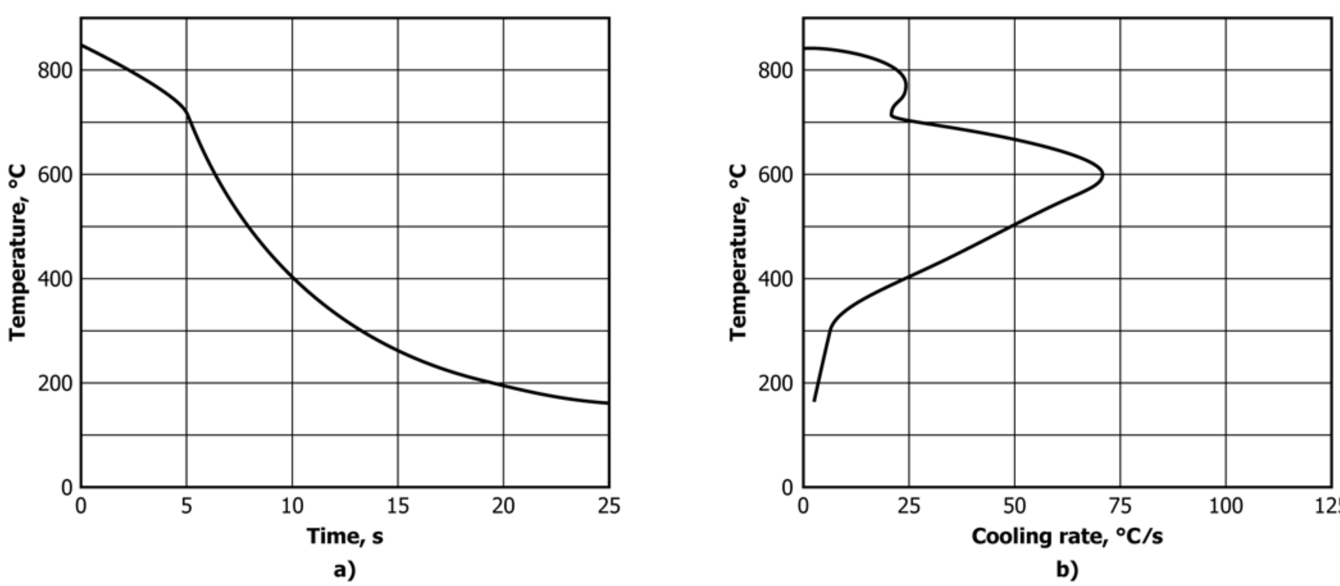


FIG. 3 Effect of Agitation Rate Variation on Cooling Curve Performance for a 15 % Aqueous Poly(Alkylene Glycol) Quenchant Solution at 30°C



A. Cooling time - temperature curve (cooling curve)

B. Cooling rate - temperature curve (cooling rate curve)

FIG. 4 Typical Temperature/Time and Temperature/Cooling Rate Plots for Test Probe Cooled in Quenching Oil

may affect cooling curve results obtained by this test method for aqueous polymer quenchants. Contaminants, such as water, hydraulic fluids, sludge, additive loss, and oil degradation, may similarly affect the cooling curve behavior of oil quenchants.

7. Apparatus

7.1 *Furnace*—Use a horizontal or vertical electrical resistance tube-type furnace capable of maintaining a constant minimum temperature of 850 °C (1562 °F) over a heated length of not less than 120 mm (4.72 in.) and a probe positioned in the center of the heating chamber. The furnace shall be capable of maintaining the probe's temperature within ±2.5 °C (4.5 °F) over the specimen length. The furnace, that is, the radiant tube heating media, shall be used with ambient atmosphere.

7.2 *Measurement System*—The temperature-time measurement system shall be a computer based data acquisition system capable of providing a permanent record of the cooling characteristics of each oil sample tested, producing a record of variation in the test probe assembly of temperature with respect to time and of cooling rate with respect to temperature.

7.3 *Probe,* shall be cylindrical, having a diameter of 12.5 mm ± 0.01 mm (0.492 in. ± 0.0004 in.) and a length of 60 mm ± 0.25 mm (2.362 in. ± 0.01 in.) with a 1.45 mm to 1.65 mm (0.057 in. to 0.065 in.) sheathed type *K* thermocouple in its geometric center. The probe shall be made of a nickel alloy 600 (UNS N06600) purchased to SAE specification (see AMS 5665), that has a nominal composition of 76.0 % Ni, 15.5 % Cr, 8.0 % Fe, 0.08 % C, and 0.25 % maximum Cu. The probe shall be attached to a support tube with a minimum