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Standard Guide for Evaluation of Hydrocarbon-Based Quench Oil¹

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1. Scope

1.1 This guide covers information without specific limits, for selecting standard test methods for testing hydrocarbon-based quench oils for quality and aging.

1.2 *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 its use.*

2. Referenced Documents

2.1 ASTM Standards:²

- D91 Test Method for Precipitation Number of Lubricating Oils
- D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- D94 Test Methods for Saponification Number of Petroleum Products
- D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
- D189 Test Method for Conradson Carbon Residue of Petroleum Products
- D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- D482 Test Method for Ash from Petroleum Products
- D524 Test Method for Ramsbottom Carbon Residue of Petroleum Products
- D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
- D974 Test Method for Acid and Base Number by Color-Indicator Titration
- D1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

D4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter

D4530 Test Method for Determination of Carbon Residue (Micro Method)

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

D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

2.2 ISO Standards:³

ISO 9950 Industrial Quenching Oils—Determination of Cooling Characteristics—Nickel-Alloy Probe Test Method, 1995-95-01

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 Quench Processing:

3.1.1.1 *austenitization, n*—heating a steel containing less than the eutectoid concentration of carbon (about 0.8 mass %) to a temperature just above the eutectoid temperature to decompose the pearlite microstructure to produce a face-centered cubic (fcc) austenite-ferrite mixture.

3.1.1.2 *dragout*—solution carried out of a bath on the metal being quenched and associated handling equipment.

3.1.1.3 *martempering, n*—cooling steel from the austenitization temperature to a temperature just above the start of merrtensite transformation (M_s) for a time sufficient for the temperature to equalize between the surface and the center of the steel, at which point the steel is removed from the quench bath and air cooled as shown in Fig. 1. (1)⁴

3.1.1.4 *protective atmosphere, n*—any atmosphere that will inhibit oxidation of the metal surface during austenitization, or it may be used to protect the quenching oil, which may be an inert gas such as nitrogen or argon or a gas used for a heat treating furnace.

3.1.1.5 *quench media, n*—any medium, either liquid (water, oil, molten salt, or lead, aqueous solutions of water-soluble polymers or salt-brines) or gas or combinations of liquid and gas (air at atmospheric pressure, or pressurized nitrogen, helium, hydrogen) such as air-water spray, used to facilitate the

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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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

⁴ The boldface numbers in parentheses refer to the list of references at the end of this standard.

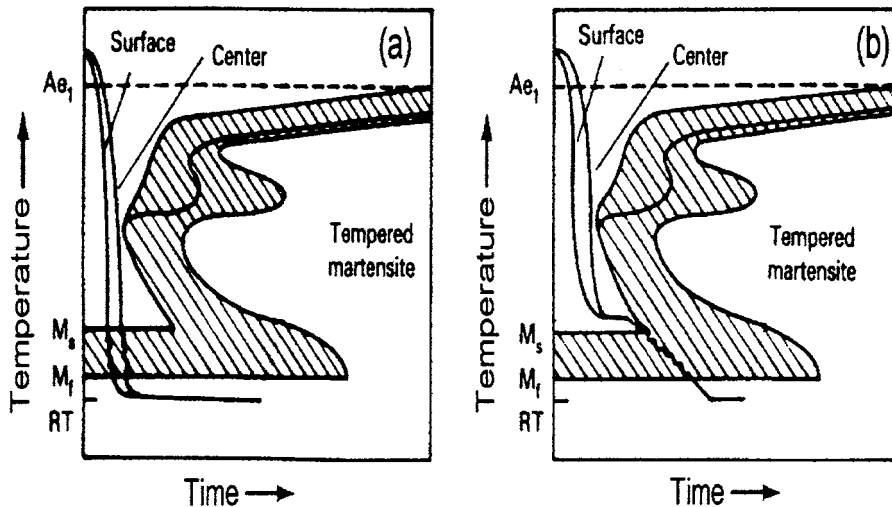


FIG. 1 (a) Conventional Quenching Cycle; (b) Martempering

cooling of metal in such a way as to achieve the desired physical properties or microstructure.

3.1.1.6 *quench severity, n*—the ability of a quenching oil to extract heat from a hot metal traditionally defined by the quenching speed (cooling rate) at 1300°F (705°C) which was related to a Grossmann H-Value or Quench Severity Factor (H-Factor). (2)

3.1.1.7 *quenching, n*—cooling process from a suitable elevated temperature used to facilitate the formation of the desired microstructure and properties of a metal as shown in Fig. 2.

3.1.1.8 *transformation temperature, n*—characteristic temperatures that are important in the formation of martensitic microstructure as illustrated in Fig. 2; A_{e1} — equilibrium austenitization phase change temperature; M_s — temperature at which transformation of austenite to martensite starts during cooling; and M_f — temperature at which transformation of austenite to martensite is completed during cooling.

3.1.2 Cooling Mechanisms:

3.1.2.1 *convective cooling, n*—after continued cooling, the interfacial temperature between the cooling metal surface and the quenching oil will be less than the boiling point of the oil, at which point cooling occurs by a convective cooling process as illustrated in Fig. 3.

3.1.2.2 *full-film boiling, n*—upon initial immersion of hot steel into a quench oil, a vapor blanket surrounds the metal surface as shown in Fig. 3. This is full-film boiling also commonly called vapor blanket cooling.

3.1.2.3 *Leidenfrost temperature, n*—the characteristic temperature where the transition from full-film boiling (vapor blanket cooling) to nucleate boiling occurs which is independent of the initial temperature of the metal being quenched as illustrated in Fig. 4. (3)

3.1.2.4 *nucleate boiling*—upon continued cooling, the vapor blanket that initially forms around the hot metal collapses and a nucleate boiling process, the fastest cooling portion of the quenching process, occurs as illustrated in Fig. 3.

3.1.2.5 *vapor blanket cooling, n*—See *full-film boiling* (3.1.2.2).

3.1.2.6 *wettability, n*—when a heated metal, such as the probe illustrated in Fig. 5, is immersed into a quenching medium, the cooling process shown in Fig. 6 occurs by initial vapor blanket formation followed by collapse, at which point the metal surface is wetted by the quenching medium. (4)

3.1.3 Quench Oil Classification:

3.1.3.1 *accelerated quenching oil, n*—also referred to as a fast or high-speed oil, these are oils that contain additions that facilitate collapse of the vapor blanket surrounding the hot metal immediately upon immersion into the quenching oil, as shown in Fig. 3.

3.1.3.2 *conventional quenching oil, n*—also called slow oils, these oils typically exhibit substantial film-boiling characteristics, commonly referred to as vapor blanket cooling due to relatively stable vapor blanket formation, illustrated mechanistically in Fig. 2.

3.1.3.3 *marquenching oils, n*—also referred to as marquenching oils or hot oils, these oils are typically used at temperatures between 95 to 230°C (203 to 446°F) and are usually formulated to optimize oxidative and thermal stability by the addition of antioxidants and because they are used at relatively high temperatures, a protective or non-oxidizing environment is often employed, which permits much higher use temperatures than open-air conditions.

3.1.3.4 *quenching oil, n*—although usually derived from a petroleum oil, they may also be derived from natural oils such as vegetable oils or synthetic oils such as poly(alpha olefin). They are used to mediate heat transfer from a heated metal, such as austenitized steel, to control the microstructure that is formed upon cooling and also control distortion and minimize cracking which may accompany the cooling process.

3.1.4 Cooling Curve Terminology:

3.1.4.1 *cooling curve, n*—a graphic representation of the temperature (T) versus cooling time (t) response of a probe. An example is illustrated in Fig. 3. (5)

3.1.4.2 *cooling curve analysis, n*—process of quantifying the cooling characteristics of a quenching oil based on the time-temperature profile obtained by cooling a preheated probe assembly (Fig. 5).

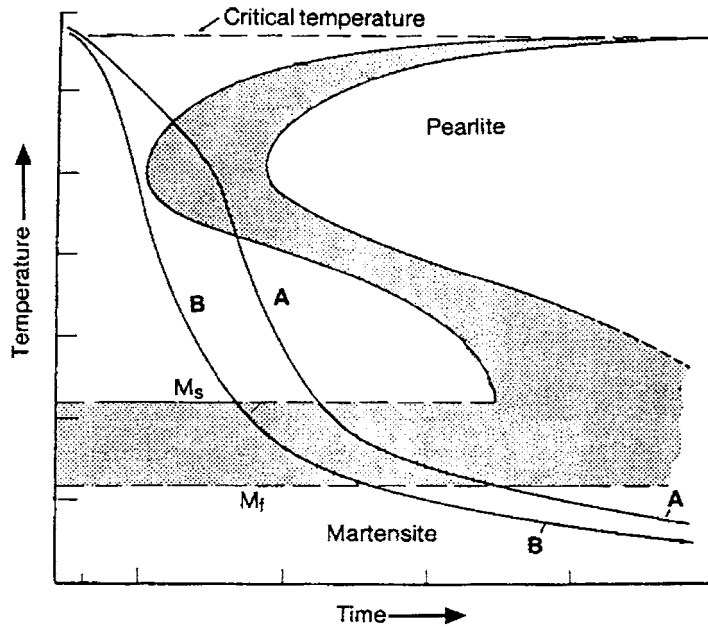


FIG. 2 Transformation Diagram for a Low-Alloy Steel with Cooling Curves for Various Quenching Media (A) High Speed Oil (B) Conventional Oil

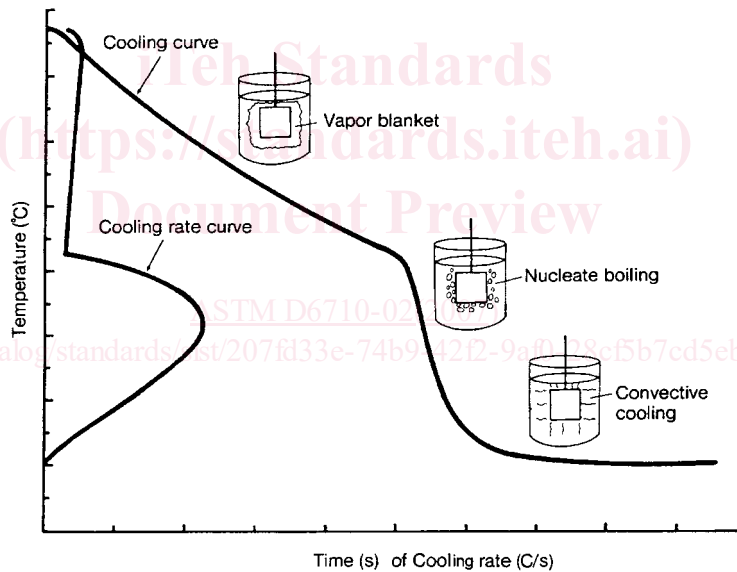


FIG. 3 Cooling Mechanisms for a Quenching Oil Superimposed on a Cooling Time-Temperature Curve and the Corresponding Cooling Rate Curve

3.1.4.3 *cooling rate curve, n*—the first derivative (dT/dt) of the cooling time-temperature curve as illustrated in Fig. 3. (5)

4. Significance and Use

4.1 The significance and use of each test method will depend on the system in use and the purpose of the test method listed under Section 6. Use the most recent editions of the test methods.

5. Sampling

5.1 *Sampling Uniformity*—Flow is never uniform in agitated quench tanks. There is always variation of flow rate and turbulence from top to bottom and across the tank. This means

that there may be significant variations of particulate contamination including sludge from oil oxidation and metal scale. For uniform sampling, a number of sampling recommendations have been developed.

5.1.1 Sampling Recommendations:

5.1.1.1 *Minimum Sampling Time*—The circulation pumps shall be in operation for at least 1 h prior to taking a sample from a quench system.

5.1.1.2 *Sampling Position*—For each system, the sample shall be taken from the same position each time that system is sampled. The sample shall be taken at the point of maximum flow turbulence. The position in the tank where the sample is taken shall be recorded.

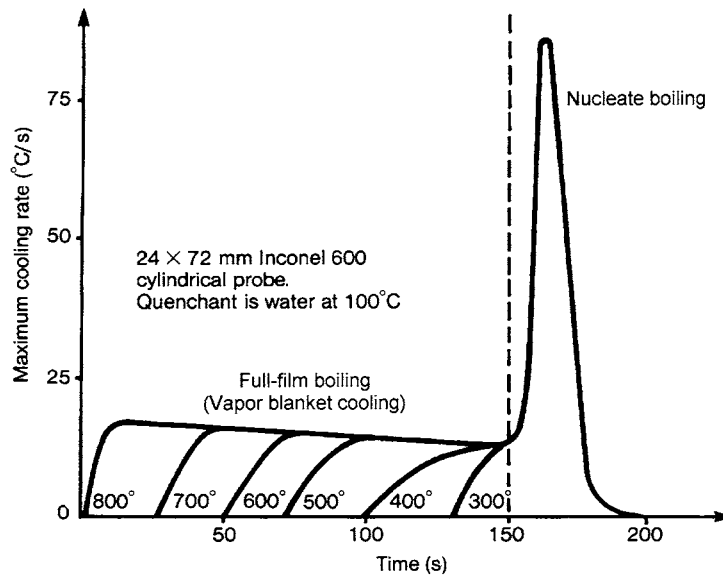
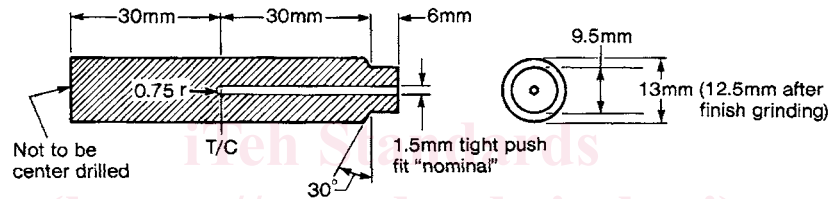
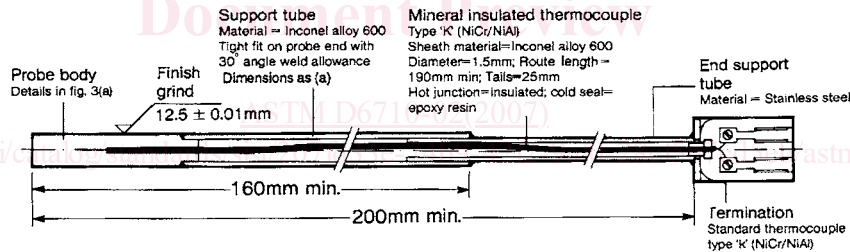


FIG. 4 Leidenfrost Temperature and its Independence of the Initial Temperature of the Metal Being Quenched



(a) Probe details



(b) General assembly

NOTE 1—Measurements are nominal. (From Test Method D6200.)

FIG. 5 Probe Details and Probe Assembly

5.1.1.3 *Sampling Valves*—If a sample is taken from a sampling valve, then sufficient quenching oil should be taken and discarded to ensure that the sampling valve and associated piping has been flushed, before the sample is taken.

5.1.1.4 *Sampling From Tanks With No Agitation*—If samples are to be taken from bulk storage tank or a quench tank with no agitation, then samples shall be taken from the top and bottom of the bulk system or quench tank. If this is not possible and the sample can only be taken from the top, then the laboratory report shall state that the results represent a sample taken from the top of the bulk system or quench tank and may not be representative of the total system.

5.1.1.5 *Effect of Quenching Oil Addition as Make-Up Due to Dragout*—It is important to determine the quantity and frequency of new quenchant additions, as large additions of

new quench oil will have an effect on the test results, in particular the cooling curve. If a sample was taken just after a large addition of new quench oil, this shall be taken into consideration when interpreting the cooling curve of this oil sample.

5.1.1.6 *Sampling Containers*—Samples shall be collected in new containers. Under no circumstances shall used beverage or food containers be used because of the potential for fluid contamination and leakage.

6. Recommended Test Procedures

6.1 *Performance-Related Physical and Chemical Properties*:

6.1.1 *Kinematic Viscosity, (Test Method D445)*—The performance of a quench oil is dependent on its viscosity, which