Heat Treatment Services—Batch Type for Equipment Used in the Petroleum and Natural Gas Industry

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**Introduction**

**Changes from the First Edition to the Second Edition**

This standard is the result of updating the requirements from API 20H, First Edition. This revision is developed based on input from the technical experts on the API 20H Task Group. The Second Edition moves this standard to a higher level of service for the petroleum and natural gas industry.

Highlights of significant changes between the First and Second Edition, include:

— Removal of typical examples of materials for each processing class listed in Table 1.
— Addition of Quality Management System (QMS) requirements for the heat treatment supplier.
— Requirement for a technical authority to be identified at the heat treatment supplier’s facility.
— Removal of Responsibilities and Duties section, considering new QMS requirements.
— Removal of Personnel Training Requirements section, considering new QMS requirements.
— Separation of HSL-1, HSL-2, and HSL-3 furnace survey and calibration requirements for improved clarity.
— Alignment of HSL-1 and HSL-2 instrumentation accuracy and calibration requirements with API 6A.
— Removal of Annex A; migrated contents into Heat Treatment Facility Capability section.
— Record retention changed.
— Allowance for part stacking under specific conditions.
— Improved clarity of Heat Treatment Quench Requirements section.
— Addition of Heat Treatment of Production Parts section.
— Improved clarity of Manufacturing Process Specification (MPS) section for each HSL.
— Improved clarity of Requirements for Heat Treatment Certification section.
Addition of Contents Section, this page
Heat Treatment Services—Batch Type for Equipment Used in the Petroleum and Natural Gas Industry

1 Scope

1.1 Purpose
This standard identifies requirements for heat treatment supplier qualification, processing, identification and traceability, and documentation of heat treatment services for use in the petroleum and natural gas industries when referenced by an applicable equipment specification.

1.2 Applicability
The requirements of this standard apply to batch heat treatment operations that establish or affect the final mechanical properties and include stress relief operations. This standard applies to carbon steel, low-alloy steel, stainless steel, and nickel-base alloys. Case hardening, induction hardening, and flame hardening are not covered by this standard.

NOTE This standard does not limit the responsibility of any manufacturer of commercial products using batch heat treating services and manufactured to an API standard from its responsibility for compliance with all applicable requirements of that API standard.

1.3 Heat Treatment Specification Levels (HSLs)
This standard establishes the requirements for three heat treatment specification levels (HSLs). These HSL designations define different levels of heat treatment technical, quality, and qualification requirements.

2 Normative References
The following referenced document is indispensable for the application of this standard. For undated references, the latest edition of the referenced document, including any amendments, apply.

API Specification Q1, Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry

ISO 9001, Quality Management Systems – Requirements

SAE AMS2750, Pyrometry

3 Terms, Definitions, Acronyms, and Abbreviations
For purposes of this standard, the following terms, definitions, and acronyms apply.

3.1 Terms and Definitions

3.1.1 acceptance criteria
Defined limits placed on characteristics of materials, processes, products, or services.

3.1.2 case hardening
A generic term covering several processes applicable to steel that change the chemical composition of the surface layer by absorption of carbon, nitrogen, or a mixture of the two and, by diffusion, create a concentration gradient. The result is a thin layer on the surface that is harder than the metal beneath it. The processes commonly used are carburizing and quench hardening, cyaniding, nitriding, and carbon nitriding.

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3.1.3 certification
Review of all heat treatment processes to meet the order requirements.

3.1.4 final inspection
The final visual examination of the heat-treated material.

3.1.5 flame hardening
A process for hardening the surfaces of hardenable ferrous alloys in which an intense flame is used to heat the surface layers above the upper transformation temperature, whereupon the work-piece or area of the surface that has been heated by direct flame impingement is immediately quenched.

3.1.6 heat sink
Metal of a defined cross section and similar heat transfer characteristics to the part(s) being heat treated and used to monitor the heat treatment temperature by the use of an embedded thermocouple.

3.1.7 heat treat
heat treatment
Specified, timed sequence of controlled heating and cooling of materials for the purpose of changing physical or mechanical properties.

3.1.8 induction hardening
A surface hardening process in which only the surface layer of a suitable ferrous work-piece is heated by electromagnetic induction to a temperature above the upper critical temperature and immediately quenched.

3.1.9 marking
Identification placed on the heat-treated material in accordance with this standard.

3.1.10 on-site activity
Activity performed at the heat treatment supplier’s facility.

3.1.11 receiving verification
Inspection and review of incoming material and attendant documentation.

3.1.12 technical authority
A competent and technically qualified person or organization with the expertise, skills, and experience regarding quality and manufacturing processes necessary to implement the requirements of this standard.

3.1.13 working zone
Usable volume of a furnace as determined by the temperature uniformity survey.

3.2 Acronyms and Abbreviations

HSL heat treatment specification level
MPS manufacturing process specification
SAT system accuracy test
TUS temperature uniformity survey
4 Heat Treatment Supplier Qualification

4.1 General

This standard establishes requirements for three heat treatment specification levels (HSLs) and four processing classes. The heat treatment supplier may qualify to one or more of the processing classes listed in Table 1 and one or more HSLs. The following paragraphs describe the conditions that, when met, allow the heat treatment supplier to receive the appropriate HSL classification level.

<table>
<thead>
<tr>
<th>Processing Class</th>
<th>Description</th>
<th>Material Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>— Normalizing</td>
<td>— Carbon/Low Alloy Steels</td>
</tr>
<tr>
<td></td>
<td>— Normalizing and Tempering</td>
<td>— Martensitic Stainless Steels</td>
</tr>
<tr>
<td></td>
<td>— Annealing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>— Stress Relieving</td>
<td></td>
</tr>
<tr>
<td>Class 2</td>
<td>— Austenitizing, Quenching, and Tempering/Aging</td>
<td>— Carbon/Low Alloy Steels</td>
</tr>
<tr>
<td></td>
<td>— Normalizing, Austenitizing, Quenching, and Tempering</td>
<td>— Martensitic Stainless Steels</td>
</tr>
<tr>
<td></td>
<td>— Precipitation-hardening Stainless Steels</td>
<td></td>
</tr>
<tr>
<td>Class 3</td>
<td>— Solution Annealing and Quenching</td>
<td>— Austenitic Stainless Steels</td>
</tr>
<tr>
<td></td>
<td>— Annealing and Quenching</td>
<td></td>
</tr>
<tr>
<td>Class 4</td>
<td>— Solution Annealing, Quenching</td>
<td>— Solution Annealed Nickel-based Alloys</td>
</tr>
<tr>
<td></td>
<td>— Solution Annealing, Quenching, and Aging</td>
<td>— Duplex and Super Duplex Stainless Steels</td>
</tr>
<tr>
<td></td>
<td>— Precipitation-hardening Nickel-based Alloys</td>
<td>— Precipitation-hardening Nickel-based Alloys</td>
</tr>
</tbody>
</table>

4.2 Quality Management System (QMS)

The heat treatment supplier shall establish, document, implement, and maintain at all times a QMS conforming to API Specification Q1 or ISO 9001. In addition, the heat treatment supplier shall be responsible for conforming to all of the applicable requirements of this standard.

4.3 Minimum Facility Requirements

The activities that shall be performed at the heat treatment supplier's facility are listed in Table 2.

<table>
<thead>
<tr>
<th>Process Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving Verification</td>
<td>On-Site Activity</td>
</tr>
<tr>
<td>Heat Treatment</td>
<td>On-Site Activity</td>
</tr>
<tr>
<td>Identification and Traceability</td>
<td>On-Site Activity</td>
</tr>
<tr>
<td>Certification</td>
<td>On-Site Activity</td>
</tr>
</tbody>
</table>
The heat treatment facility shall have the on-site equipment and the personnel needed to perform the heat treatment of product under the scope of this standard. This includes an on-site technical authority for all heat treat operations. Subsequent processing such as finish machining, painting, or testing is beyond the scope of this standard.

4.4 Qualification Requirements

4.4.1 Qualification shall consist of a completed heat treatment operation with one or more HSLs and processing classes. Acceptance criteria shall be in full conformance with the requirements of the governing material specification. Processing class qualification shall be in accordance with Table 3.

Table 3—Processing Class Qualification Limitations

<table>
<thead>
<tr>
<th>Processing Class</th>
<th>HSL Required</th>
<th>Class Qualified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>HSL 1, HSL 2, or HSL 3</td>
<td>Class 1</td>
</tr>
<tr>
<td>Class 2</td>
<td>HSL 1, HSL 2, or HSL 3</td>
<td>Class 1 and Class 2</td>
</tr>
<tr>
<td>Class 3</td>
<td>HSL 1, HSL 2, or HSL 3</td>
<td>Class 1 and Class 3</td>
</tr>
<tr>
<td>Class 4</td>
<td>HSL 2 or HSL 3</td>
<td>Class 1, Class 3, and Class 4</td>
</tr>
</tbody>
</table>

NOTE Qualification to Processing Classes 2 and 4 qualifies the heat treatment supplier to Processing Classes 1, 2, 3, and 4.

4.4.2 Batch heat treatment furnaces shall be evaluated by the heat treatment supplier in order to establish qualification to the applicable HSL. Furnace qualification shall meet the requirements indicated in Table 4 for the applicable sections of this standard.

Table 4—Batch Heat Treatment Furnace Test Requirements

<table>
<thead>
<tr>
<th>HSL</th>
<th>Processing Class</th>
<th>TUS</th>
<th>Calibration</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSL-1</td>
<td>4.4.1</td>
<td>6.2.4</td>
<td>6.2.5</td>
<td>---</td>
</tr>
<tr>
<td>HSL-2</td>
<td>4.4.1</td>
<td>6.3</td>
<td>6.3</td>
<td>---</td>
</tr>
<tr>
<td>HSL-3</td>
<td>4.4.1</td>
<td>6.4.1</td>
<td>6.4.1</td>
<td>6.4.1</td>
</tr>
</tbody>
</table>

4.5 Heat Treatment Specification Levels

4.5.1 Heat Treatment Specification Level 1 (HSL-1)

4.5.1.1 The TUS and instrumentation requirements for heat treatment equipment in conformance with HSL-1 shall be in accordance with 6.2.

4.5.1.2 A temperature uniformity survey (TUS) shall be performed within 1 year prior to use of the furnace. The TUS shall be for the full temperature operating range of the furnace in accordance with 6.2.

4.5.1.3 The heat treatment supplier shall record the quench media temperature at start, peak, and finish of the quench cycle. Records shall be maintained.

4.5.1.4 The heat treatment supplier shall have the capability of using multiple contact or heat sink thermocouples, where applicable.

4.5.2 Heat Treatment Specification Level 2 (HSL-2)

4.5.2.1 The requirements of HSL-1 shall apply with the following modifications.

4.5.2.2 A TUS shall be performed every six months minimum. The TUS shall be for the full temperature operating range of the furnace in accordance with 6.2.
4.5.2.3 Quench media temperature shall be recorded during the entire quench process. Records shall be maintained.

4.5.2.4 Additional temperatures shall be added to the TUS, as required, to ensure that no two adjacent survey temperatures are greater than 600 °F (335 °C) apart (see section 6.3).

4.5.2.5 Thermocouples shall be verified for accuracy or replaced at least every three months, in accordance with the heat treatment supplier's written procedure. Records shall be maintained.

4.5.3 Heat Treatment Specification Level 3 (HSL-3)

4.5.3.1 The pyrometric requirements for heat treatment equipment in conformance with HSL-3 shall be in accordance with 6.4.

4.5.3.2 Quench media temperature shall be recorded during the entire quench process. Records shall be maintained.

4.5.3.3 The heat treatment supplier shall have the capability of using multiple contact or heat sink thermocouples.

NOTE Conformance to the requirements of HSL-3 also qualifies as HSL-1 or HSL-2.

5 Heat Treatment Facility Capability

5.1 General

The heat treatment supplier shall complete and maintain a current list for furnace equipment and quench equipment used in heat treatment to this standard. The following variables shall be documented. The variable documentation format shall be determined by the heat treatment supplier.

- Type of Furnace
- Heating Process
- Working Zone Dimensions
- Temperature Range of the Furnace TUS
- Temperature Tolerance of the Furnace TUS
- TUS Frequency
- Furnace Atmospheres
- Method of Transfer to Quench Tank
- List Quench Tanks That the Material Can Be Transferred to From This Furnace:
  - In 60 seconds or less
  - Between 60 and 90 seconds, inclusive
- Quench Tank Media
- Quench Tank Capacity
- Describe Agitation System
- Use of Cooling Towers or Chillers

5.2 Identification and Traceability

The heat treatment supplier shall have a documented procedure for control of identification and traceability throughout the process. The procedure shall include, as a minimum:

a) the method for verifying traceability upon receipt of material,

b) the method for marking the product, when required,
c) the method for ensuring traceability of product after any processing where the original marking could be removed, and

d) requirements for maintenance or replacement of identification or traceability marks.

6 Heat Treatment Equipment Temperature Uniformity Survey (TUS) and Calibration

6.1 Calibration

Equipment used to record heat treatment or other equipment necessary to control heat treatment operations shall be identified, controlled, calibrated, and adjusted at specified intervals to maintain the accuracy required by this standard. Calibration shall be performed in accordance with documented instructions, which are consistent with nationally or internationally recognized standards specified by the heat treatment supplier. Records shall be maintained.

6.2 HSL-1 TUS and Instrumentation Requirements

6.2.1 TUS Temperature Tolerances (High Heat Only)

The temperature at any point in the working zone of a furnace used for austenitizing, normalizing, annealing, or solution annealing shall not vary by more than ±25 °F (±14 °C) from the furnace set-point temperature after the furnace working zone has been brought up to temperature.

6.2.2 TUS Temperature Tolerances (Low Heat Only)

Furnaces used for tempering, aging, and/or stress-relieving shall not vary by more than ±15 °F (±8 °C) from the furnace set-point temperature after the furnace working zone has been brought up to temperature.

6.2.3 TUS Temperature Tolerances (Combined Low and High Heat Furnaces)

For furnaces used for both the heat treatment operations specified in 8.2.1 and 8.2.2, the heat treatment supplier shall define the temperature range for each operation. The furnace temperature tolerance shall conform to the requirements specified in 8.2.1 or 8.2.2, as appropriate.

6.2.4 TUS Method

6.2.4.1 A TUS within the furnace working zone(s) shall be performed on each furnace at the maximum and minimum temperatures for each range for which the furnace is being used.

a) A minimum of nine thermocouple test locations shall be used for all furnaces having a working zone greater than 10 ft³ (0.3 m³) and not greater than 1125 ft³ (31.5 m³). For each additional 125 ft³ (3.5 m³) beyond 1125 ft³ (31.5 m³) of furnace working zone surveyed, at least one additional thermocouple test location shall be used, up to a maximum of 40 thermocouples. See Figures 1 and 2 for examples of thermocouple locations. Each additional thermocouple location shall be equally spaced in the central additional working zone volume.

b) For furnaces having a working zone less than or equal to 10 ft³ (0.3 m³), the temperature survey may be made with a minimum of three thermocouples located either at the front, center, and rear or at the top, center, and bottom of the furnace working zone.

6.2.4.2 After insertion of the temperature-sensing devices, readings shall be taken at least once every three minutes to determine when the temperature of the furnace working zone approaches the bottom of the temperature range being surveyed.

6.2.4.3 Once the furnace temperature has reached the set-point temperature, the temperature of all test locations shall be recorded at 2-minute intervals, maximum, for at least 10 minutes. Then, readings shall be taken at 5-minute intervals, maximum, for sufficient time (at least 30 min) to determine the recurrent temperature pattern of the furnace working zone.
6.2.4.4 Before the furnace set-point temperature is reached for austenitizing, normalizing, or solution annealing, none of the temperature readings shall exceed the set-point temperature by more than 25 °F (14 °C). Before the furnace set-point temperature is reached for tempering or aging, none of the temperature readings shall exceed the set-point temperature by more than 15 °F (8 °C).

6.2.4.5 After the furnace control set-point temperature is reached, no temperature reading shall vary beyond the limits specified.

6.2.4.6 When a furnace is repaired or rebuilt, a new temperature survey shall be carried out before the furnace is used for heat treatment, except for minor repairs as noted below.
Minor repairs or replacement of damaged or malfunctioning components or scheduled preventive maintenance that restores the furnace to its original condition and are not expected to affect the temperature uniformity characteristics of the furnace shall not require repeating the TUS. Examples include, but are not limited to, the following:

a) replacing a burner or tile with another duplicate burner or tile,

b) refractory repair using material with similar thermal properties,

c) replacing a control or monitoring sensor to its previously documented location,

d) replacing heating system components (e.g. gas regulator, valve, metering device, heating elements, etc.),

e) restoring original combustion pressure settings and tuning constants,

f) replacing a controller with an identical controller with the same tuning constants,

g) system accuracy test failure,

h) correction of furnace pressure control problem, and/or

i) repair of furnace door seals.

6.2.4.7 All furnace repairs shall be documented. The organization responsible for quality assurance shall make the determination whether an additional TUS is required based on the repairs made and the particular furnace configuration before returning the furnace to service.

6.2.5 Instruments

6.2.5.1 General

Automatic controlling and recording instruments shall be used. Furnace controlling thermocouples shall be in the furnace at the same location and orientation specified during the last TUS. Thermocouples shall be protected from furnace atmosphere by means of suitable protective devices.

6.2.5.2 Accuracy

The controlling and recording instruments used for heat-treatment processes shall be accurate to ±1% of their full-scale range.

6.2.5.3 Calibration

Temperature controlling and recording instruments shall be calibrated at least once every three months. Equipment used to calibrate production equipment shall be accurate to ±0.25% of full-scale range.

6.3 HSL-2 TUS and Instrumentation Requirements

The requirements specified for HSL-1 are required for HSL-2.

Additional temperatures shall be added to the TUS, as required, to ensure that no two adjacent survey temperatures are greater than 600 °F (335 °C) apart.

6.4 HSL-3 TUS and Instrumentation Requirements

6.4.1 General

Heat treatment equipment used for conformance with HSL-3 shall be in accordance with SAE AMS2750, *Pyrometry*.

6.4.2 Furnace Class Requirements
6.4.2.1 The applicable furnace class for the heat treatment equipment and temperature range to which the furnace is qualified shall be identified in the furnace calibration report.

6.4.2.2 Heat treatment furnaces shall be certified to an allowable furnace class for the applicable heat treatment type, as shown in Table 5.

Table 5—HSL-3 Heat Treatment Requirements

<table>
<thead>
<tr>
<th>Heat Treatment Type</th>
<th>SAE AMS2750 Furnace Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class 1</td>
</tr>
<tr>
<td></td>
<td>TUS Tolerance</td>
</tr>
<tr>
<td>Normalizing</td>
<td>±5°F (±3°C)</td>
</tr>
<tr>
<td>Annealing</td>
<td>X</td>
</tr>
<tr>
<td>Solution Annealing</td>
<td>X</td>
</tr>
<tr>
<td>Austenitizing</td>
<td>X</td>
</tr>
<tr>
<td>Tempering</td>
<td>X</td>
</tr>
<tr>
<td>Precipitation Hardening</td>
<td>X</td>
</tr>
<tr>
<td>Aging</td>
<td>X</td>
</tr>
<tr>
<td>Stress Relieving</td>
<td>X</td>
</tr>
</tbody>
</table>

6.4.3 Pyrometry Procedure Requirements

The heat treat supplier shall have a documented procedure addressing the technical requirements of SAE AMS2750. These requirements shall include the following.

a) Temperature Sensors (thermocouples):
   1) Thermocouple usage,
   2) Sensor calibration,
   3) Reuse of thermocouples,
   4) Type of thermocouple used for various applications,
   5) Calibration procedure and frequency of calibration for the types of thermocouples used.

b) Instrumentation:
   1) Instrument types used by the heat treatment supplier,
   2) Instrument calibration frequency and required calibration accuracy,
   3) Instrument calibration procedure.

c) System Accuracy Tests (SATs):
   1) Instrumentation and sensors used for SATs,
   2) Frequency of SATs,
3) Procedure for conducting the SAT,
4) Maximum allowable SAT difference.

d) Furnace Temperature Uniformity Surveys (TUSs):
   1) The surveyed volume (working zone) of each furnace,
   2) The operating temperature range of each furnace.
   3) Procedure for conducting TUSs (initial and periodic) to include:
      i) Survey temperatures to be used,
      ii) Furnace load condition,
      iii) Number of thermocouples to be used,
      iv) Location of survey thermocouples,
      v) Data collection procedure.

6.5 Records

Records of furnace calibration and surveys shall be maintained per section 12.

7 Heat Treatment Procedures

7.1 General

The heat treatment supplier shall maintain documented procedures that describe the controls associated with heat treatment services and the applicable requirements of this standard.

Heat treatment shall be performed in accordance with a procedure that includes a description of the methods used for heat treatment and the methods used for data recording, data processing, data reporting and for certification of the results.

7.2 Furnace Atmosphere

When a controlled atmosphere is required, the heat treatment supplier shall have a written procedure addressing the following process control variables:

a) furnace atmospheres,
b) instrumentation,
c) calibration of atmospheric controllers,
d) verification of atmosphere,

7.3 Process Validation

Demonstration of the hardness, mechanical properties, and/or order requirements obtained shall be considered satisfactory evidence of process validation. The frequency of process validation shall be defined by the heat treatment supplier.

8 Furnace Loading

8.1 Products shall be heat treated such that there is sufficient spacing between parts. Except for normalizing or annealing, spacers or an arrangement of products shall be used to assure that the products are not directly upon each other
and there is adequate circulation around the products during heat treatment.

8.1.1 Material shall be placed on racks or supports to ensure exposure of all surfaces to heating and quenching media and to minimize warpage during heating and quenching. Long parts shall be supported, as needed, to prevent sagging.

8.1.2 Material shall not be placed directly on the furnace hearth (floor).

8.1.3 Metal trays, piers, or fixtures that allow the furnace atmosphere to circulate around and under the part(s) shall be used.

8.1.4 For complex geometries, special fixtures may be needed.

8.2 Material shall be within the working volume of the furnace that was established in the TUS. In gas-fired furnaces, the material shall be loaded in such a manner that avoids any flame impingement from the burners.

8.3 Furnaces should be inspected to ensure that doors/openings are properly sealed, and that there are no excessive hot spots in the furnace walls. Racks and supports should be inspected for functional capability.

8.4 When required by the purchaser or referenced specification, a furnace loading diagram shall be prepared for each load heat treated, showing the part geometry and contact or heat sink thermocouple location(s).

9 Heat Treatment Quench Requirements

9.1 General Requirements

9.1.1 Quench tanks should be located in close proximity to the solution annealing or austenitizing furnace, depending on material grade to be quenched, and be easily accessible. This will minimize transfer time and heat loss of the load during the transfer.

9.1.2 The transfer time from furnace to the quench tank should be as fast as possible, but shall be no more than 90 seconds for all materials other than the duplex class of stainless steel.

9.1.3 For duplex and super duplex stainless steel, the maximum transfer time to quench shall be 60 seconds.

9.1.4 The transfer time shall be measured from the time the furnace door is fully opened or the furnace roof is fully removed until the component(s) is completely submerged into the quenching bath.

9.1.5 The heat treatment supplier shall have a documented quench process procedure addressing the method of tank agitation, use of chillers and recirculation systems, and method of controlling quench media temperature.

9.1.6 The quenching bath should be free from contamination that could affect the quenching process. Bath maintenance programs shall be established in accordance with the heat treatment supplier's written procedure.

9.1.7 Proper agitation is critical. Quench tanks shall have a mechanical means (propellers, pumps, etc.) of circulating the quench media to optimize the cooling rate. Agitators shall be placed so that adequate circulation is maintained throughout the quench tank when a load is being quenched.

9.1.8 An agitation system check shall be made in accordance with the heat treatment supplier's written procedure to ensure the adequacy of the agitation system.

9.1.9 Forced or compressed air as a means of agitation of a liquid quench bath is not permitted.

9.1.10 Raising and lowering of a part or furnace load by crane or mechanical table within the quench tank as a means of agitation, is prohibited.

9.1.11 Products shall be quenched such that there is sufficient spacing between parts. Except for normalizing and annealing, spacers or an arrangement of products shall be used to assure that the products are not directly upon each other and there is good flow of quenchant around the products during quenching.
9.1.12 When parts are submerged in a liquid quench, the parts shall remain fully submerged for the duration of the quench process.

9.1.13 The heat treatment supplier shall have a documented procedure or work instruction defining the required minimum time a part is held in the quench tank.

9.1.14 Agitation should be sufficient to break up the vapor blanket that forms at the surfaces of the hot, immersed part(s).

NOTE During quenching the vapor blanket will act as an insulator and greatly reduce the cooling rate. Proper quench tank agitation, by pumps, impellers, or similar equipment, will normally produce noticeable rise in the level of quench media. A quench tank with a single pump located at one end, for example, might not be acceptable because part of the load could be shielded from the quench media flow.

9.2 Water Quench

9.2.1 The water quench media temperature shall not exceed 100 °F (40 °C) at the start of the quench and shall not exceed 120 °F (50 °C) at any time during the quench cycle.

9.2.2 Water quench tanks shall be adequately sized for the furnace loads. This may require the use of supplemental heat exchangers or chillers. At a minimum, at least one of the following two methods shall be used to assure adequate and timely heat removal from the load being quenched.

9.2.2.1 Quench tanks shall have a minimum of one US gallon (3.785 liters) of quench water for every pound (0.454 kilograms) of furnace load being quenched.

9.2.2.2 The heat treatment supplier shall establish a documented procedure that validates the effectiveness of the quench when the parameters of 9.2.2.1 are not met. This procedure shall be supplemented by actual test data showing the heat removal properties of the quench bath on a heat treatment lot of product.

9.3 Oil Quench

9.3.1 When oil quenching is performed, only oil formulated by the quench oil manufacturer specifically for heat treatment quenching operations shall be used.

9.3.2 Oil quench media shall be maintained within the manufacturer’s recommended temperature range. These requirements are necessary to minimize the possibility of oil quench tank fires.

9.4 Polymer Quench

9.4.1 Polymer quench media shall be maintained within the manufacturer’s recommended temperature range.

9.4.2 The concentration of the polymer shall be checked by the heat treatment supplier, on at least a weekly basis, by means of a refractometer or similar means in accordance with the heat treatment supplier's written procedure and adjusted as necessary. Results shall be documented and maintained for a minimum of 1 year.

9.4.3 The heat treatment supplier shall have the polymer checked by the polymer manufacturer or independent laboratory for concentration, viscosity, and contamination at least once every 12 months. The results shall be documented and maintained per section 12 and comply with the heat treatment supplier’s written procedure.

10 Heat Treatment Equipment Maintenance

The heat treatment supplier shall have a documented and fully implemented preventative maintenance procedure that addresses the following equipment, as a minimum:

a) transfer system/loading systems,

b) furnaces,
11 Heat Treatment of Production Parts

11.1 General

Production parts shall be heat treated and quenched using equipment qualified in accordance with this standard. The heat treatment supplier shall have an MPS to document the heat treatment process in accordance with this standard.

11.2 Manufacturing Process Specification (MPS)

11.2.1 General

The heat treatment supplier shall maintain a manufacturing process specification (MPS) to include, as a minimum, allowable levels for all heat treatment variables including the process control variables listed in 11.2.2, the quench variables listed in 11.2.3, and the inspection and test requirements listed in 11.2.4. Heat treatment variables, quench variables, and inspection and test results shall be documented and maintained per section 12.

11.2.2 Heat Treatment Variables

The following heat treatment variables shall be documented:

- heat treatment times and temperatures for each processing cycle;
- method of monitoring temperature;
- dimensions at time of heat treatment;
- furnace atmosphere requirements.

The following additional heat treatment variables shall be applicable for HSL-2 and HSL-3:

- furnace loading diagram, orientation, quantity or maximum weight, and spacing of parts;
- temperature ramp up rate;
- temperature ramp down rate.

11.2.3 Quench Variables

The following quench variables shall be documented:

- quench media;
- quench media start, peak, and finish temperature.

The following additional quench variables shall be applicable for HSL-2 and HSL-3:

- type of agitation (forced, horizontal or vertical quench, ID/OD, etc.);
- transfer time to quench;
- time in quench.
11.2.4 Inspection and Test Requirements

The following inspection and test requirements shall be documented:

— visual examination;
— traceability and marking;
— final hardness test (when required);

12 Records

12.1 General

Records shall be maintained for a minimum of ten (10) years, unless otherwise specified in this standard. Documents and data may be in any type of media (hard copy or electronic) and shall be:

— signed and dated;
— maintained to demonstrate conformance to specified requirements;
— legible;
— retained and readily retrievable;
— stored in an environment to prevent damage, deterioration, or loss; and
— available and auditable by the purchaser.

12.2 Document Control

The heat treatment supplier shall establish and maintain documented procedures to control the documents and data required by this standard.

12.3 Records to be Maintained by Heat Treatment Supplier

The following records shall be maintained by the heat treatment supplier:

— heat treatment process records;
— heat treatment procedure;
— heat treatment procedure process qualification record (records of testing results); and
— heat treatment personnel qualification records.

12.4 Requirements for Heat Treatment Certification

When heat treatment is performed in accordance with this standard, the following information shall be included in the heat treatment certificate issued to the purchaser:

— conformance to API 20H and applicable HSL,
— name of heat treatment supplier,
— address of heat treatment supplier,
— date of certification,
— authorized signature and title of signatory,
— number of parts/components/joint level serialization per heat treatment load, when required by product specification,
— heat treatment lot number/job number/traveler number,
— material heat number/re-melt ingot number,
— material type, grade, or alloy designation,
— description of material being heat treated (dimension, shape, part number, serial number, if applicable),
— description of heat treatment process (solution annealing, age hardening, etc.):
  — heat treatment temperatures,
  — time at specified temperature,
  — quench media - temperature at start, peak, and finish of the quench,
  — transfer time, if required,
  — continuous quench media temperature record, if required,
  — method of temperature monitoring (furnace thermocouple, attached thermocouple, heat sink thermocouple),
  — furnace charts, if required,
  — furnace identification, if required,
— applicable heat treatment criteria/specification,
— furnace loading map per heat treatment load, if required.

13 Handling, Storage, and Shipping

Heat treated material shall be packaged for storage or transit in accordance with the documented procedure of the heat treatment supplier or the customer's purchasing document.