Heat Treatment Services – Continuous Line, for Equipment Used in the Petroleum and Natural Gas Industry

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Contents

To be populated prior to publication.
1 Scope

1.1 Purpose

This standard specifies requirements for the qualification of suppliers of continuous line heat treatment services used in the manufacture of equipment for the petroleum and natural gas industries.

1.2 Applicability

This standard is applicable to suppliers providing heat treatment services where API product standards specify this standard as a requirement for conformance. The requirements of this standard apply to continuous and semi-continuous heat treatment operations that can establish or affect the final mechanical properties. This standard is applicable to products in tubular, bar, plate, forgings, castings and upset forged forms. Heat treat that imparts surface hardening or case hardening is outside the scope of this document.

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

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies, except that new editions may be used on issue and become mandatory upon the effective date specified by the publisher or 12 months from the date of the revision (where no effective date is specified).

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

ISO
ISO 9001, Quality management systems - Requirements

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For purposes of this standard, the following terms and definitions apply:

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

3.1.2 continuous furnace
Heating device through which material is moved intentionally at a constant rate during the processing cycle.

3.1.3 cycle time
Time within the furnace for austenitizing or tempering.
3.1.4 exit temperature
The measured temperature of the material exiting the austenitizing or tempering furnaces.

3.1.5 final inspection
The final visual examination and documentation release of the heat-treated material.

3.1.6 heat treat lot
The quantity of material from the same grade, size, processed in the same manner in the furnaces, using the same process parameters. Additional product specifications may restrict the use of multiple heats (cast).

3.1.7 load sensor
Sensors that are attached to or in contact with production material or are buried in load of production material.

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

3.1.9 on-site activity
Activity performed at the heat treatment supplier's facility.

3.1.10 pre-heat zone(s)
The section of the furnace that precedes the control zone(s).

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

3.1.12 semi-continuous operational process
Heating device through which material is moved intentionally with a predetermined start-stop-start pattern during the processing cycle.

3.1.13 system accuracy test
SAT
An on-site comparison of the instrument/leadwire/sensor readings or values, with the readings or values of a calibrated test instrument/leadwire/sensor to determine if the measured temperature deviations are within applicable requirements. These are performed to ensure the accuracy of the furnace control and recorder system in each control zone.

3.1.14 temperature uniformity survey
TUS
A test, or series of tests where calibrated field test instrumentation and sensors or heat sensitive material are used to measure temperature variation within the qualified furnace work zone, prior to and after thermal stabilization.

3.1.15 work zone
The volume based on the boundaries established by the heat treater for each furnace. This may exclude pre-heat and entry/exit sections. As applicable to temperature uniformity survey methods: (Volumetric, Plane, Probe methods).

3.1.16 zone
An independently controlled section of the furnace.

3.2 Acronyms and Abbreviations
For the purposes of this recommended practice, the following acronyms and abbreviations apply:

MPS  Manufacturing Process Specification
SAT  System Accuracy Test
TUS  Temperature Uniformity Survey

4 Heat Treatment Supplier Qualification
4.1 Establishment of the Process Being Qualified
The following continuous line heat treatment processes are covered in this document. The heat treater will qualify for one or more of the processes described below:

4.1.1 Continuous Process “Class A”– no interruption in austenitize-quench-temper, or solution anneal and quench.
   a) Induction, gas fired, or electric heating in austenitizing and temper may be used.
   b) Quench by surface spray, bath immersion, surface spray/ID quench.

4.1.2 Semi Continuous Hybrid “Class B”– continuous austenitizing and quench followed by interrupted batch type temper.
   a) Induction, gas fired, or electric heating in austenitizing and tempering may be used.
   b) Quench by surface spray, bath immersion, surface spray/ID quench.
   c) Batch type temper (API 20H requirements shall apply for the batch type temper process).

4.1.3 Continuous Process “Class C”– baskets or loose grouped components conveyed together through austenitizing–quenching-temper, or solution annealing-quench.
   a) Open or closed end thermal heating by gas, electric, or propane fired.
   b) Quench by surface spray, bath immersion, surface spray/ID quench.

4.1.4 Continuous process “Class D”– does not involve a quench.
Normalizing, Annealing or Stress Relieving, by induction, electric, or gas fired.
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 specification.

5 Responsibilities and Duties

5.1 General

It is the responsibility of the heat treatment supplier to ensure that it:

a) performs all heat treatment in accordance with specified standards and applicable quality control criteria;

b) performs only heat treatment for which it is adequately equipped and staffed;

c) performs only heat treatment for which its employees are adequately qualified;

d) ensures equipment is calibrated and personnel performing calibration are qualified in accordance with the requirements of the supplier’s written procedure;

e) ensures facility and equipment is properly maintained;

f) informs the purchaser of any discrepancy or limitation imposed on the requested heat treatment by such factors as size, traceability, form, shape, material or procedure;

g) calls to the attention of the purchaser any irregularity or deficiency noted in the procurement documents;

h) promptly submits formal reports of all heat treatment to the purchaser; and

i) informs the purchaser of noncompliance of the specified standards or procurement document requirements.

5.2 Personnel Training Requirements

Personnel performing heat treatment (operators/supervisors) shall be trained and qualified in accordance with requirements of the heat treatment supplier’s written procedure. Records of training and qualification shall be maintained.

6 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 ensuring traceability of product after any processing where the original marking could be removed or burned off;

c) requirements for maintenance or replacement of identification or traceability marks;

d) the method used to maintain individual part level traceability if required by specification; and

e) the method for final marking of the product, if required by specification.

7 Calibration

7.1 Equipment Calibration

Equipment used to record heat treatment or other equipment necessary to control heat treatment operations shall be identified, controlled, and calibrated 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.
7.2 Temperature Uniformity Survey (TUS)

7.2.1 General

The heat treater shall document a procedure that confirms TUS compliance to one or more methods listed below.

There are four acceptable TUS Methods for Continuous Furnaces (class A, C, D section 4.2), as listed below:

a) Volumetric Method
b) Plane Method
c) Probe Method
d) Mechanical Property Evaluation

7.2.2 Volumetric Method- Raw Material processing

Continuous furnaces may be surveyed with TUS sensors that are arranged in a volumetric type fixture, which is conveyed through the furnace. The number and location of TUS sensors is determined by the furnace work zone volume in order to measure the entire work zone.

The heat treat vendor shall establish the boundaries of the “work zone” in their furnaces. This may exclude preheat zones or furnace entry/furnace exit areas that will not be applicable to the survey.

The arrangement of these volumetric TUS sensors shall be as follows:

a) Eight (8) TUS sensors shall be located at the corners and one shall be in the center. If the work zone is a cylindrical shape, three (3) sensors shall be located on each end, 120 degrees apart. One at the center of the cylinder, and the other two distributed to best represent the work zone. The additional sensors required (beyond the minimum 9) in Table 1 shall be located to best represent the work zone.

b) Furnaces that utilize baskets, trays, or pallets to convey product through the furnace, are conducive this type of survey.

c) The number of TUS sensors for this method is dependent upon the size of the work zone. See Table 1.

<table>
<thead>
<tr>
<th>Furnace Volume (less than)</th>
<th>3 cubic ft.</th>
<th>225 cubic ft.</th>
<th>300 cubic ft.</th>
<th>400 cubic ft.</th>
<th>600 cubic ft.</th>
<th>800 cubic ft.</th>
<th>1000 cubic ft.</th>
<th>2000 cubic ft.</th>
<th>3000 cubic ft.</th>
<th>4000 cubic ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(.085 cubic m)</td>
<td>(6.4 cubic m)</td>
<td>(8.5 cubic m)</td>
<td>(11 cubic m)</td>
<td>(17 cubic m)</td>
<td>(23 cubic m)</td>
<td>(28 cubic m)</td>
<td>(57 cubic m)</td>
<td>(85 cubic m)</td>
<td>(113 cubic m)</td>
<td></td>
</tr>
<tr>
<td>Number of Sensors</td>
<td>5</td>
<td>9</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>20</td>
<td>23</td>
<td>25</td>
</tr>
</tbody>
</table>

In conducting the survey all parameters reflecting the normal operation of the furnace shall be in place.

Initial Surveys shall be conducted at the highest and lowest traverse speed used for production. Periodic surveys may be conducted at any production speed.

Readings shall be recorded at least every 2 minutes, with at least three sets of readings recorded per zone.

Continuous furnaces that are used for austenitizing or normalizing shall meet a temperature uniformity of +/- 25F (+/-14C).
Continuous furnaces that are used for tempering or stress relieving shall meet a temperature uniformity of +/- 15F (+/-8C).

Furnaces that are used for both must be qualified to meet a temperature uniformity of +/- 15F (+/-8C).

The heat treat vendor shall establish the type of Instruments they utilize in the operation of their furnaces. The type instruments being utilized will have a direct impact on the Survey frequency. See Table 2 and Table 3.

Permitted interval extensions are listed in Table 4.

If the temperature uniformity is not within the tolerances stated herein, the cause of the deviation shall be determined and documented. Corrective action shall be taken, and the equipment shall not be used for additional processing until a new survey has been performed and meets expectations. This failure data shall be kept as a record, along with the actions taken to correct the reason for the failure.

Table 2 - Classification of Instrument Types

<table>
<thead>
<tr>
<th>Control Sensor expectations</th>
<th>Instrument Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>One (1) control sensor per zone that controls and displays temperature</td>
<td>A</td>
</tr>
<tr>
<td>Each work zone has a recording instrument that is either connected to a control sensor,</td>
<td>B</td>
</tr>
<tr>
<td>or a second sensor in the same area</td>
<td>C</td>
</tr>
<tr>
<td>At least two (2) additional recording sensors in each work zone,</td>
<td>D</td>
</tr>
<tr>
<td>representing the coldest and hottest areas of that zone</td>
<td></td>
</tr>
<tr>
<td>At least one (1) recording load sensor in each zone (See definition 3.1.16)</td>
<td></td>
</tr>
<tr>
<td>Each work zone shall have an over temperature protection sensor</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 - Raw Material –Instrument Type and TUS Survey Intervals

<table>
<thead>
<tr>
<th>Temperature uniformity</th>
<th>Instrument Type</th>
<th>Initial TUS survey</th>
<th># of successful Surveys</th>
<th>Extended TUS interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 15F (+/-8 C)</td>
<td>D</td>
<td>Quarterly</td>
<td>4</td>
<td>Semi-Annually</td>
</tr>
<tr>
<td></td>
<td>B or C</td>
<td>Semi-Annually</td>
<td>3</td>
<td>Annually</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Semi-Annually</td>
<td>2</td>
<td>Annually</td>
</tr>
<tr>
<td>+/- 25F (+/-14 C)</td>
<td>D</td>
<td>Quarterly</td>
<td>4</td>
<td>Semi-Annually</td>
</tr>
<tr>
<td></td>
<td>B or C</td>
<td>Semi-Annually</td>
<td>3</td>
<td>Annually</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Semi-Annually</td>
<td>2</td>
<td>Annually</td>
</tr>
</tbody>
</table>
Table 4 – Permitted Calibration / Test interval Extension

<table>
<thead>
<tr>
<th>Calibration/Test Interval</th>
<th>Allowable extension beyond due date (calendar days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly</td>
<td>1</td>
</tr>
<tr>
<td>Bi-weekly</td>
<td>2</td>
</tr>
<tr>
<td>Monthly</td>
<td>3</td>
</tr>
<tr>
<td>Quarterly</td>
<td>4</td>
</tr>
<tr>
<td>Semi-Annually</td>
<td>6</td>
</tr>
<tr>
<td>Annually</td>
<td>12</td>
</tr>
</tbody>
</table>

7.2.3 Plane Method

7.2.3.1 Continuous furnaces may be surveyed with TUS sensors that are arranged in a plane which is perpendicular to the furnace conveyance direction. The sensors shall be arranged in the plane so that they measure the entire work zone. Furnaces that utilize baskets, trays, or pallets to convey thru the furnace, are conducive this type of survey.

7.2.3.2 The number of TUS sensors for this method is dependent upon the size of the work zone.

a) For furnaces having a work zone height of 1 foot or less, the minimum number of TUS sensors shall be 3, with 1 additional TUS sensor for each 2 feet in width over 8 feet.

b) For furnaces having a work zone height of over 1 foot, and work zone cross sections up to 8 square feet the minimum number of TUS sensors shall be 5.

c) For work zone cross sections greater than or equal to 8 square feet the minimum number of TUS sensors shall be 7.

d) For work zone cross sections greater than or equal to 16 square feet the minimum number of TUS sensors shall be 9.

7.2.3.3 The location of the TUS sensors is also dependent upon the size of the work zone.

a) For furnaces having a work zone height of 1 foot or less, two TUS sensor locations shall be within 3 in. of the opposite work zone side corners. One TUS sensor shall be at the center. Additional TUS sensors shall be uniformly distributed throughout a plane perpendicular to the conveyance direction.

b) For furnaces having a work zone height of over 1 foot, and work zone cross sections up to 8 square feet, 4 (four) TUS sensors shall be within 3 in. of the work zone corners and the remainder shall be at, and around the center area.

c) For work zone cross sections greater than 8 square feet, 4 (four) TUS sensors shall be within 3 in. of the work zone corners and the remainder shall be at, and around the center area.

7.2.3.4 In conducting the survey all parameters reflecting the normal operation of the furnace shall be in place.

7.2.3.5 Initial Surveys shall be conducted at the highest and lowest traverse speed used for production. Periodic surveys may be conducted at any production speed.

7.2.3.6 Readings shall be recorded at least every 2 minutes, with at least three sets of readings recorded per work zone.

7.2.3.7 Continuous Furnaces that are used for austenitizing or normalizing shall meet a temperature uniformity of +/- 25F (+/-14C).
Continuous Furnaces that are used for tempering or stress relieving shall meet a temperature uniformity of +/- 15F (+/-8C).

Furnaces that are used for both shall be qualified to meet a temperature uniformity of +/- 15F (+/-8C).

7.2.3.8 The heat treat vendor shall establish the type of instruments they use in the operation of their furnaces. The type of instruments being used will have a direct impact on the survey frequency. See Table 2 and Table 3.

Permitted interval extensions are listed in Table 4.

7.2.3.9 If the temperature uniformity is not within the tolerances stated herein, the cause of the deviation shall be determined and documented. Corrective action shall be taken, and the equipment shall not be used for additional processing until a new survey has been performed and meets expectations. This failure data shall be kept as a record, along with the actions taken to correct the reason for the failure.

7.2.4 Probe Method
7.2.4.1 Continuous furnaces may be surveyed with TUS sensors that are inserted through the side walls, hearth, or roof of the work zones.

The heat treater shall establish and define the actual work zones and work zone volume of each furnace.

The number of the TUS sensors for this method is dependent upon the size of the work zone. Reference Table 1 for the number of sensors required.

The location of the sensors is dependent upon the work zone volume as follows:

For Work zone volumes greater than 3 cubic feet, 8 (eight) TUS sensors shall be located at the corners, and one at the center. If the work zone is cylindrical shaped, 3 (three) TUS sensors shall be located on the outside diameter, 120 degrees apart. One TUS sensor shall be located in the center, and the other two shall be located to best represent the qualified work zone.

For work zones greater than 225 cubic feet, the additional sensors required by Table 1 shall be uniformly distributed to best represent the qualified work zone.

Each of the inserted TUS sensors must be within 3 in. of the locations described above.

7.2.4.2 TUS survey requirements:

For Austenitizing Furnaces, the survey shall be done within +/- 150 F of the normal operating temperature range mid-point for that furnace. (The normal operating range for the austenitizing furnace shall be documented).

For Tempering, furnaces shall be done at the normal operating temperature range for that furnace. (The normal operating range for the tempering furnace shall be documented).

The survey temperature shall be conducted within a range of the lowest operating temperature to plus 300F and at the highest operating temperature minus 300F. If the difference between the lowest and highest temperature range is less than or equal to 300F, only one temperature survey is required.

Readings shall be taken every 2 minutes and a reading of at least 1 controlling, monitoring, or recording sensor in each surveyed zone shall be taken every 5 minutes for a minimum of 30 minutes one the zone temperature has stabilized.

7.2.4.3 Continuous Furnaces that are used for austenitizing or normalizing shall meet a temperature uniformity of +/- 25F (+/-14C).

7.2.4.4 Continuous Furnaces that are used for tempering or stress relieving shall meet a temperature uniformity of +/- 15F (+/-8C).

Furnaces that are used for both, must be qualified to meet a temperature uniformity of +/- 15F (+/-8C).
7.2.4.5 The heat treat vendor shall establish the type of instruments they utilize in the operation of their furnaces. The type instruments being utilized will have a direct impact on the survey frequency. See Table 2 and Table 3.

Permitted interval extensions are listed in Table 4.

7.2.4.6 Temperature uniformity survey failures. If the temperature uniformity is not within the tolerances stated herein, the cause of the deviation shall be determined and documented. Corrective action shall be taken, and the equipment shall not be used for additional processing until a new survey has been performed and meets expectations. This failure data shall be kept as a record, along with the actions taken to correct the reason for the failure.

7.2.5 Mechanical Property Evaluation Method.

7.2.5.1 Upon startup of a new furnace, or re-commissioning of an old furnace, initial testing shall be performed. An alloy that is heat treated frequently shall be selected for evaluation. This evaluation method shall also be performed on an annual basis.

7.2.5.2 Initial and annual testing temperature selection:
Austenitizing shall be done at the normal operating temperature range for the furnace being evaluated. This operating range shall be +/- 150°F from the normal operating temperature. (The normal operating range for the austenitizing furnace shall be documented.)
Tempering shall be done at the normal operating temperature range for the furnace being evaluated. (The normal operating range for the tempering furnace shall be documented.)
Testing shall be conducted within a range of the lowest operating temperature to plus 300°F and at the highest operating temperature minus 300°F. If the difference between the lowest and highest temperature range is less than or equal to 300°F, only one test is required.

7.2.5.3 Initial and annual testing.
For the temperature ranges specified above, the sampling frequency shall be:
Test samples from the temper furnace shall be selected to insure uniformity that is maintained throughout the process. One example would be to select samples from the beginning, middle, and end of a production run. The number of total tests shall be a minimum of 10 to satisfy the initial and annual requirements. The 10 tests may incorporate different heat treat lots.

7.2.5.4 Additionally, monthly analysis of mechanical property trends shall be done for the material heat treated that month. This analysis shall be performed with standard Statistical Methods. Once control limits have been established any shift outside upper or lower controls limits will require corrective action.

NOTE Property trends can only be performed with sufficient data which is dictated by the amount of material being heat-treated.

7.2.5.5 If out-of-control conditions are discovered, an evaluation of the possible effects of the non-conformance on product processed since the last successful corresponding test shall be performed and documented.

7.2.5.6 Testing expectations are dictated by the product being heat-treated. The heat treater shall establish the required testing based on their product mix. Testing may be any of the following:

- Tensile properties (recommended Tensile strength)
- Hardness properties

The following test methods can be used in conjunction with the above methods:
7.2.6 Allowable survey methods for Class “B” Semi Continuous (Batch Type Temper)

7.2.6.1 To qualify the austenitizing furnaces, any one of the four methods shown above (7.2.1-7.2.5) shall be acceptable.

7.2.6.2 For the associated Batch Type Temper Furnace in this process, a standard Batch type TUS shall be performed.

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

7.2.6.4 A minimum of nine thermocouple test locations shall be used for all furnaces having a working zone greater than 10 ft³ (0.3 m³). For each 125 ft³ (3.5 m³) of furnace working zone surveyed, at least one thermocouple test location shall be used, up to a maximum of 40 thermocouples. See Figures 1 and 2 for examples of thermocouple locations.

7.2.6.5 For furnaces having a working zone less than 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.

7.2.6.6 After insertion of the temperature-sensing devices, readings shall be taken at least once every 3 minutes to determine when the temperature of the furnace-working zone approaches the bottom of the temperature range being surveyed.

7.2.6.7 Once the temper 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.

7.2.6.8 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).

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

7.2.7 Calibration Records to be maintained.

7.2.7.1 Report shall show normal operating ranges of Austenitizing and Tempering furnaces.

7.2.7.2 Initial surveys for new and re-conditioned furnaces

7.2.7.3 TUS details:

7.2.7.4 For volumetric, probe, and plane methods, include records of the Work zone boundaries, number of sensors and locations, traverse speeds, recording frequency, process type (normalize, austenitize, temper, or stress relieve), and instrument type used.

7.2.7.5 For mechanical property method, annual mechanical property surveys, monthly surveys and control limits, testing method(s) used to perform the evaluation, from 7.2.4.6.

7.2.7.6 Pass/fail criteria

7.2.7.7 Relevant authority.

7.2.7.8 Actual temperatures being surveyed.
8 Process control

8.1 Instruments

Automatic controlling and recording instruments shall be used. Thermocouples shall be located in the furnace working zone(s) and protected from furnace atmosphere by means of suitable protective devices. The heat treat supplier shall have a documented procedure addressing the technical requirements of the instruments being used. These requirements shall include:

a) Instrument types used by the heat treatment supplier  
b) Instrument calibration frequency and calibration accuracy  
c) Instrument calibration procedure

8.2 System Accuracy tests (SATs)

The SAT is performed as an on-site comparison of the furnace controlling equipment, to calibrated devices/equipment to ensure the accuracy of controlling and recording devices. The SATs shall be performed in each zone that is used for production heat treatment. The SATS shall also be performed on additional systems that qualify instrumentation as types A, B, C or D. (Table 2) SATS shall be performed using field test instruments, thermocouples, and extension wire that meet Table 5. SAT frequency is established in Table 5 after defining the Instrument types A, B, C, or D that are being employed in the process. (See Table 2) The Frequency of these tests is shown in Table 5.

Table 5 - Raw Material – Instrument Type and System Accuracy Tests (SAT) Interval

<table>
<thead>
<tr>
<th>Temperature Uniformity</th>
<th>Instrument Type</th>
<th>Normal SAT Interval</th>
<th>Maximum Allowable SAT Interval</th>
<th>Max SAT Difference F</th>
<th>Max SAT Difference C</th>
<th>% of reading</th>
<th>Max Permitted Adjustment F</th>
<th>Max Permitted Adjustment C</th>
<th>% of max op temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 15F (+/- 8 C)</td>
<td>D</td>
<td>Monthly</td>
<td>Quarterly</td>
<td>+/- 4</td>
<td>+/- 2.2</td>
<td>0.4</td>
<td>+/- 8</td>
<td>+/- 5</td>
<td>.38</td>
</tr>
<tr>
<td></td>
<td>B or C</td>
<td>Quarterly</td>
<td>Semi-Annually</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Quarterly</td>
<td>Semi-Annually</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+/- 25F (+/- 14 C)</td>
<td>D</td>
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<td>Quarterly</td>
<td>+/- 5</td>
<td>+/- 2.8</td>
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<td>+/- 13</td>
<td>+/- 7</td>
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<td>B or C</td>
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<td>Semi-Annually</td>
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<td>Quarterly</td>
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8.3 Heat Treatment Quench requirements.

8.3.1 The heat treat supplier shall identify the quench process used in their facility and it shall be a part of the heat treat procedure. Examples of some standard quench processes are listed below:

a) Ring Spray quenching, static, or dynamic type quench.  
b) Inside diameter (ID) quench lance for tubular components.  
c) Forced (ID) pressure flow for tubular components.  
d) Immersion bath type quench (water, oil, or polymer).
8.3.2 The water quench input temperature for water spray quench shall be monitored and recorded for each heat treat lot. The temperature shall meet the product specification expectations.

8.3.3 Water immersion bath type quench processes: Water quench media shall not exceed 100°F at the start of the quench, and shall not exceed 120°F at any time during the quench cycle.

8.3.4 When oil batch type quenching is performed, only oil manufactured specifically for heat treatment quenching operations shall be used. Quench media temperature shall meet the manufacturers recommended temperature range.

8.3.5 Polymer batch type quenching shall be maintained within the manufacturers recommended temperature range.

8.3.6 The concentration of the polymer bath shall be checked by the heat treat supplier, on a regular basis, by means of a refractometer or similar device, as documented in the heat treatment suppliers written procedure. The heat treatment supplier shall have the polymer checked by the polymer manufacturer or independent laboratory for concentration, viscosity and contamination at a frequency not to exceed 6 months. Results shall be documented.

8.3.7 Products quenched in baskets, or multiple components immersed in a bath type quench, shall be properly spaced to ensure that the components get a good flow of quenchant.

8.3.8 The heat treatment supplier shall identify the agitation method used for bath type quenches. Additionally the volume of the tank (gallons) shall be recorded in the Heat treatment procedure. The immersion time of these bath type quenches shall also be a part of the procedure.

8.3.9 For all quench methods, the heat treater shall have a documented procedure that addresses the contamination of the quench media, as part of their preventive maintenance.

8.3.10 The heat treatment supplier shall have a documented quench process procedure addressing method of tank agitation, use of chillers and recirculation system and method of controlling quench media temperature as applicable.

8.3.11 Proper agitation is critical for batch type quench systems. 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.

8.3.12 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 this can be part of the Heat Treatment supplier’s preventive maintenance system.

8.3.13 Bath quenched products shall be quenched in single layers. If this is not practical, spacers or the arrangement of product shall be used to ensure that the products are not directly upon each other and there is good flow of quenchant around the products during quenching.

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

8.4 Movement of Product
Speed of movement of the product through the furnaces, shall be documented and recorded. The procedure shall also identify the method used to determine the cycle time.

The manufacturer shall have a method to verify that speed of product movement thru the furnace is validated. This shall be documented in a procedure.

8.5 Records
Records of furnace calibration and surveys shall be maintained for a period of not less than five (5) years.

9 Heat Treatment Procedures
9.1 General
The heat treatment supplier shall maintain documented procedure(s) that describes 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.

9.2 Furnace Atmosphere.
Typically continuous line heat treatment processes are open to the atmosphere and are not specifically controlled.

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

a) management of atmospheres,
b) instrumentation,
c) calibration of atmospheric controllers,
d) verification of atmosphere, and
e) safety.

9.3 Process Validation
Demonstration of the mechanical properties and/or order requirements obtained on production parts shall be considered satisfactory evidence of process validation.

Validation of the quench process. The heat treater shall validate the quench process through mechanical property, microstructure or As-quenched hardness evaluations, through a documented procedure. The procedure shall address the testing method, acceptance criteria, and frequency.

For a given process, there should be documented evidence that supports that the process can furnish consistent mechanical properties.

The documented evidence shall be available for review, to confirm process validation.

9.4 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 system,
b) furnace,
c) quench systems (nozzles, agitation for bath type quenches,
d) thermocouples part of the calibration program, and
e) temperature recording and controlling devices.
10 Manufacturing Process Specification

10.1 General

The heat treatment supplier shall maintain a manufacturing process specification (MPS) (recipe) to include, as a minimum, allowable levels for all heat treatment parameters including the process control variables listed in 11.1.1 and the inspection and test requirements listed in 11.1.2. Heat treatment variables, quench variables and inspection and test results shall be documented.

10.2 Heat Treatment Variables

The following are heat treatment parameters, based on product characteristics (grade, configuration, bar/tube, and size) as applicable:

a) charge size, or configuration of the load, including spacing, as applicable,
b) furnace zone temperatures,
c) quench pressure for dynamic spray quench processes,
d) throughput speed, and
e) quench variables.

The following are quench parameters, as applicable:

d) quench media and type (water spray, water bath, polymer bath, oil bath),
e) quench temperatures, as applicable,
f) water spray quench alignment, as applicable, and
g) time in quench of bath type quenches.

10.3 Test Requirements

The following tests, as applicable:

a) final hardness test,
b) mechanical testing, and
c) as-quenched hardness test.

11 Heat Treatment Records

11.1 General

The records required by this standard are necessary to substantiate that all services provided meet this standard and conform to the specified requirements.

11.2 Document Control

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

11.3 Records to be Maintained by Heat Treatment Supplier

11.3.1 Heat treatment process records.
11.3.2 Heat treatment procedure.
11.3.3 Heat treatment procedure process qualification record (records of testing results).
11.3.4 Applicable heat treatment personnel qualification records.
11.3.5 Records required by this document.

11.4 Minimum Requirements for Heat Treatment Certificates

11.4.1 Name of heat treatment supplier.
11.4.2 Address of heat treatment supplier.
11.4.3 Date of certification.
11.4.4 Authorized signature and title of signatory.
11.4.5 Number of parts/components/joint level serialization per heat treatment load, when required by product specification.
11.4.6 Heat treatment lot number/job number/traveller number.
11.4.7 Material heat number/re-melt ingot number.
11.4.8 Material type, grade, or alloy designation,
11.4.9 Description of material being heat treated (dimension, shape, part number, serial number, if applicable),
11.4.10 Description of the process (austenitize, quench and temper, etc.).
11.4.11 Heat treatment temperatures if required.
11.4.12 Time at specified temperature, if required by the customer specification.
11.4.13 Quench media, if required.
11.4.14 Quench media temperature record, if required.
11.4.15 Furnace charts, if required.
11.4.16 Furnace identification, if required.
11.4.17 Applicable heat treatment criteria/specification, if required.

12 Record Retention

Records required by this standard shall be maintained for a minimum of five (5) years, or as dictated by other applicable standards. Documents and data may be in any type of media (hard copy or electronic) and shall be:

a) signed and dated;
   b) maintained to demonstrate conformance to specified requirements;
   c) legible;
   d) retained and readily retrievable;
   e) stored in an environment to prevent damage, deterioration, or loss;
   f) available and auditable by the purchaser.

13 Handling, Storage and Shipping

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

14 Minimum Facility Requirements

The activities that shall be performed at the heat treatment supplier’s facility are listed in Table 6.

The heat treatment facility shall have the on-site equipment and the personnel to perform the required processes to perform the heat treatment of product under the scope of this standard. Subsequent processing such as finish machining, painting, or testing is beyond the scope of this standard.

<table>
<thead>
<tr>
<th>Item</th>
<th>Process Activity</th>
<th>Location</th>
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<tr>
<td>1</td>
<td>Receiving Verification</td>
<td>On-Site Activity</td>
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<tr>
<td>2</td>
<td>Final Heat Treatment</td>
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</tr>
<tr>
<td>3</td>
<td>Marking</td>
<td>On-Site Activity</td>
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<tr>
<td>4</td>
<td>Final Inspection</td>
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Bibliography

1) AMS 2750, Pyrometry