BALLOT # 6545

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

API STANDARD 20N

SECOND EDITION, XXXXX

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Introduction

Changes from the First Edition to the Second Edition:

This standard represents an update to the requirements from API 20N, First Edition. It was revised with input from technical experts in the API 20N Task Group. The Second Edition elevates the 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:

- Bring in the minimum facility requirements to Section 4 Heat Treatment Supplier Qualification
- Removed Marking and Final Inspection from minimum facility requirements and added identification and traceability and certification
- Reformatted Section 6 Equipment Calibration to include updates from recent industry standards such AMS 2750
- Updated figured for thermocouple locations to improve clarity
- Improved the evaluation method for optical pyrometer equipment calibration using principles from ASTM 1100
- Provided an evaluation criteria for temperature stability for induction lines
- Improved clarity of heat treatment process control
- Updated record retention to be inline with Q1 and other API standards

1 Scope

1.1 Purpose

This standard specifies requirements for the qualification of suppliers of continuous line heat treatment processes 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 specifications 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. For batch type heat treatment refer to API 20H. 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 using continuous line heat treatment services and manufactured to an API specifications from its responsibility for compliance with all applicable requirements of that API specifications.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

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

ISO 9001, *Quality management systems—Requirements*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 For purposes of this standard, the following terms, definitions, acronyms, and abbreviations apply.

3.1.1
final inspection
The final visual examination, and documentation release of the heat-treated material.

3.1.2
heat treat lot
The quantity of material from the same grade and size. Material is processed uninterrupted in the same continuous line and with the same process parameters. Additional product specifications may restrict the use of multiple heats. The quantity of material of the same grade, heat, and size, where the material is processed in the same manner using a continuous line uninterrupted.

3.1.3
load sensor
Sensors that are attached to or in contact with production material or are buried in load of production material.

3.1.4
marking
Identification placed on the heat-treated material in accordance with this standard.

3.1.5
on-site activity
Activity performed at the heat treatment supplier's facility.

3.1.6
preheat zone(s)
The section of the furnace that precedes the work zone(s).

3.1.7
qualified operating temperature range
A range of temperature that represents the +/- max/min uniformity tolerances within which parts or raw material will be processed.

3.1.8
quench media
Usually oil, water, water/polymer mixtures, or gaseous mediums.

3.1.9
quench system
Equipment used to quench which may include tanks, nozzles, agitators, heat exchangers, etc.

3.1.10
receiving verification
Inspection and review of incoming material and attendant documentation.

3.1.11
sensor
A device designed to detect or measure temperature (i.e. thermocouple, resistance temperature detector (RTD), infrared pyrometer, etc.)
3.1.12
semi-continuous heat treatment operation
Heating system 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/lead wire/sensor readings or values, with the readings or values of a calibrated test instrument/lead wire/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
work zone(s)
The volume based on the boundaries established by the heat treater for each furnace including continuous lines that exhibit multiple work zones of different temperatures. This may exclude preheat and entry/exit sections. As applicable to temperature uniformity survey methods: (Volumetric, Plane, Probe methods).

3.2 Acronyms and Abbreviations

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 treatment supplier will qualify for one or more of the processes described in 4.1.1 through 4.1.4.

4.1.1 Continuous Process "Class A"

This process involves 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 media by surface spray, bath immersion, ID quench.

4.1.2 Semi-Continuous Hybrid "Class B"

This process involves a combination of batch and continuous austenitizing, quench and or tempering.

a) Induction, gas fired, or electric heating in austenitizing and tempering may be used.
b) Quench media by surface spray, bath immersion, ID quench.
c) Batch type temper

4.1.3 Continuous Process "Class C"

This process involves 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 media by surface spray, bath immersion, ID quench.

4.1.4 Continuous Process "Class D"

This process does not involve a quench such as normalizing, annealing or stress relieving, aging, tempering 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 standard.

4.3 Minimum Facility Requirements

The heat treat facility shall be capable of heat treating in compliance with this standard and at a minimum meet the requirements of Table 1.

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 1- Minimum Facility Requirements

Item	Process Activity	Location
1	Receiving Verification	On-site Activity
2	Heat Treatment	On-site Activity
3	Identification and Traceability	On-site Activity
4	Certification	On-site Activity

NOTE If the organization chooses to outsource any activity within the scope of its quality management system, the organization shall ensure that all applicable elements of its quality management system are satisfied and shall maintain responsibility for product conformance to specified requirements.

5 Responsibilities and Duties

5.1 General

It is the responsibility of the heat treatment supplier at a minimum shall perform the following:

a) the manufacturing process specification and heat treatment design is capable to meet the agreed upon purchasers' requirements

b) all heat treatment is performed in accordance with specified standards and applicable quality control criteria;

c) performs only heat treatment of which it is adequately equipped and staffed;

d) performs only heat treatment of which its employees are qualified;

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

f) ensures facility and equipment is maintained;

g) 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;

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

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

j) 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.

5.3 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 purchaser.

e) the method for marking of heat treated product, if required by purchaser.

6 Calibration

6.1 General

6.1.1 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.

6.1.2 Accepted Evaluation Methods

The heat treatment supplier shall document a procedure that confirms compliance to acceptable methods for continuous lines, as listed below:

a) Volumetric method

b) Plane method

c) Probe method

d) Mechanical property evaluation

e) Optical pyrometer method (for induction only)

6.2 Temperature Uniformity Survey (TUS)

6.2.1 General Requirements for Volumetric, Plane, and Probe Methods

6.2.1.1 TUS survey requirements shall be as follows:

a) Initial Surveys shall be conducted at the maximum and minimum temperatures of the qualified operating temperature range(s) for production.

b) The qualified operating temperature range shall be documented.

c) Periodic surveys shall be required per the intervals in Table 2.

d) For all furnaces, the periodic survey shall be done within the qualified operating temperature range(s) so that the temperature is no more than 300 °F (167 °C) above the minimum and no more than 300 °F (167 °C) below the maximum temperature.

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

f) Total survey time shall be not less than 30 minutes.

g) Continuous lines that are used for austenitizing or normalizing shall meet a temperature uniformity of ±25 °F (±14 °C).

h) Continuous lines that are used for tempering, stress relieving, precipitation hardening, and aging shall meet a temperature uniformity of ±15 °F (±8 °C).

i) Furnaces that are used for both shall be qualified to meet a temperature uniformity of ±15 °F (±8 °C).

6.2.1.2 The heat treatment supplier shall establish the type of instruments they utilize 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.

Table 2—Instrument Type and TUS Survey Intervals

Temperature Uniformity	Instrument Type	Initial TUS Survey	# of Successful Surveys	Extend TUS Interval
±15 °F (±8 °C)	D	Quarterly	4	Semi-annually
	B or C	Semi-annually	3	Annually
	A	Semi-annually	2	Annually
±25 °F (±14 °C)	D	Quarterly	4	Semi-annually
	B or C	Semi-annually	3	Annually
	A	Semi-annually	2	Annually

Table 3—Classification of Instrument Types

	Instrument Type			
Control Sensor Requirements	**A**	**B**	**C**	**D**
One control sensor per zone that controls and displays temperature.	X	X	X	X
Each work zone has a recording instrument that is either connected to a control sensor, or a second sensor in the same area.	X	X	X	X
At least two additional recording sensors in each work zone, representing the coldest and hottest areas of that zone.	X		X	
At least one recording load sensor in each zone (see 3.1.15).	X	X		
Each work zone shall have an over temperature protection sensor.	X	X	X	X

Permitted interval extensions are listed in Table 4.

Table 4—Permitted Calibration/Test Interval Extension

Calibration/Test Interval	Allowable Extension Beyond Due Date (Calendar Days)
Weekly	1
Bi-weekly	2
Monthly / Bi-Monthly	3
Quarterly / 4 Months	4
Semi-annually	6
Annually	12

6.2.1.3 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 requirements. This failure data shall be kept as a record, along with the actions taken to correct the reason for the failure.

6.2.1.4 The failure of one or more TUS sensors at corner locations, any two adjacent TUS sensors, or a number exceeding the requirements in Table 5 shall require corrective action to be taken and the TUS repeated.

Table 5. Allowable number of TUS sensor failures

Total Number of TUS Sensors	Allowable Number of TUS Sensor Failures
3 to 9	None
10 to 16	1
17 to 23	2
24 to 39	3
≥ 40	No more than 10%

6.2.2 Volumetric Method—Raw Material Processing

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

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

a) Eight TUS sensors shall be located at the corners and one shall be in the center. If the work zone is a cylindrical shape, three 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 nine) in Table 5 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 to this type of survey.

c) The number of TUS sensors for this method is dependent upon the size of the work zone. See Table 6.

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

Table 6—Number of TUS Sensors for the Volumetric & Probe Method

Furnace Volume (less than)	3 cubic ft.^{3} (0.085 m^3)	225 cubic ft. (6.4 m^3)	300 cubic ft. (8.5 m^3)	400 cubic ft. (11 m^3)	600 cubic ft. (17 m^3)	800 cubic ft. (23 m^3)	1000 cubic ft. (28 m^3)	2000 cubic ft. (57 m^3)	3000 cubic ft. (85 m^3)	4000 cubic ft. (113 m^3)
Number of Sensors	5	9	12	13	14	15	16	20	23	25
ft^3 per Sensor	<1	25	25	31	43	53	63	100	130	160

TUS sensor or recording channel failure at the corner location of a rectangle/square work zone or periphery (top/bottom or front/back) locations of a cylinder work zone is not permitted. A temporary condition such as a short or loose connection where normal temperature indications is restored shall not be considered as a failed TUS sensor.

6.2.3 Plane Method

6.2.3.1 Continuous lines 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 through the furnace, are conducive to this type of survey.

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

a) For furnaces having a work zone height of 1 ft (300 mm) or less, the minimum number of TUS sensors shall be three, with one additional TUS sensor for each 2 ft (610 mm) in width over 8 ft (2.4 m).

b) For furnaces having a work zone height more than 1 ft (300 mm), and work zone cross sections up to 8 ft^2 (0.75 m^2) the minimum number of TUS sensors shall be five.

c) For work zone cross sections greater than or equal to 8 ft^2 (0.75 m^2), the minimum number of TUS sensors shall be seven.

d) For work zone cross sections greater than or equal to 16 ft^2 (1.5 m^2), the minimum number of TUS sensors shall be nine.

6.2.3.3 location of the TUS sensors is also dependent upon the size of each work zone.

a) For furnaces having a work zone height of 1 ft (300 mm) 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 ft (300 mm), and work zone cross sections up to 8 ft^2 (0.75 m^2), four TUS sensors shall be within 3 in. (76 mm). 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 ft^2 (0.75 m^2), four TUS sensors shall be within 3 in. (76 mm) of the work zone corners and the remainder shall be at, and around the center area.

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

6.2.3.5 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 requirements. This failure data shall be kept as a record along with the actions taken to correct the reason for the failure.

6.2.4 Probe Method

6.2.4.1 Continuous lines may be surveyed with TUS sensors that are inserted through the side walls, hearth, or roof of the work zones.

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

6.2.4.3 The number of the TUS sensors for this method is dependent upon the size of the work zone. Reference Table 6 for the number of sensors required.

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

a) For work zone volumes greater than 3 ft^3 (0.085 m^3), eight TUS sensors shall be located at the corners, and one at the center. If the work zone is cylindrical shaped, 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.

b) For work zones greater than 225 ft^3 (6.37 m^3), the additional sensors required by Table 6 shall be uniformly distributed to best represent the qualified work zone.

c) Each of the inserted TUS sensors shall be within 3 in. of the locations described above.

6.2.4.4 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 requirements. This failure data shall be kept as a record, along with the actions taken to correct the reason for the failure.

6.2.5 Mechanical Property Evaluation Method

6.2.5.1 Upon startup of a new continuous line, or re-commissioning of an old continuous line, 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.

Initial and annual testing temperature selection:

a) Austenitizing shall be done at the normal operating temperature range for the continuous line being evaluated. This operating range shall be ±150 °F (83 °C) from the normal operating temperature. The normal operating range for the austenitizing continuous line shall be documented.

b) Tempering shall be done at the normal operating temperature range for the continuous line being evaluated. The normal operating range for the tempering continuous line shall be documented.

c) Testing of the product shall be conducted from samples heat treated within a range of the lowest qualified operating temperature range(s) to plus 300 °F (167 °C) and at the highest operating temperature to minus 300 °F (167 °C). If the difference between the lowest and highest temperature range is less than or equal to 300 °F (167 °C), only one test is required.

6.2.5.2 For the temperature ranges specified above, the initial and annual testing frequency shall be:

a) Test samples from the temper continuous line shall be selected to ensure uniformity 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.

b) Additionally, a documented analysis of mechanical property trends shall be done for the material heat treated. This analysis should 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.

6.2.5.3 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.

6.2.5.4 Mechanical testing performed as part of the mechanical property evaluation method shall conform to applicable requirements of national and international testing standards (e.g. ASTM, ISO, etc.)

6.2.5.5 Testing requirements are dictated by the product being heat treated. The heat treatment supplier shall establish the required testing based on their product mix. Testing may be any of the following:

a) Tensile properties (recommended tensile strength)

b) Hardness properties

6.2.5.6 The following test methods can be used in conjunction with the above methods:

a) As-quenched hardness

b) Microstructure evaluation

c) Charpy impacts

6.2.6 Allowable Survey Methods for Class “B” Semi-continuous (Batch Type Temper)

6.2.6.1 To qualify the austenitizing furnaces, any one of the methods shown in 7.2 shall be acceptable.

6.2.6.2 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.

6.2.6.3 A minimum of nine thermocouple test locations shall be used for all furnaces having a working zone greater than 10 ft^3 (0.3 m^3). For each 125 ft^3 (3.5 m^3) of furnace working zone surveyed, at least one thermocouple test location shall be used up to a maximum of 40 thermocouples. See Figure 1 and Figure 2 for examples of thermocouple locations.

6.2.6.4 furnaces having a working zone less than 10 ft^3 (0.3 m^3), 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.

6.2.6.5 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.

6.2.6.6 Once the temper furnace temperature has reached the set-point temperature, the temperature of all test locations shall be recorded at 2-minute intervals at 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.

6.2.6.7 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).

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

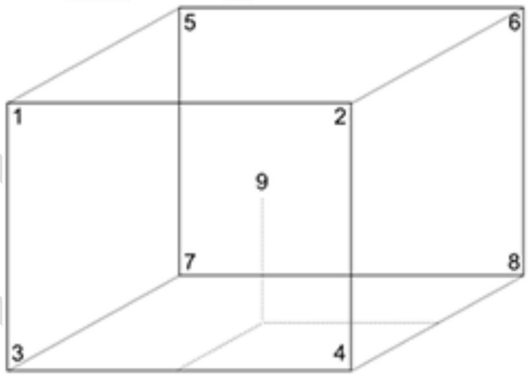

Figure 1—Thermocouple Locations—Rectangular Furnace (Working Zone)

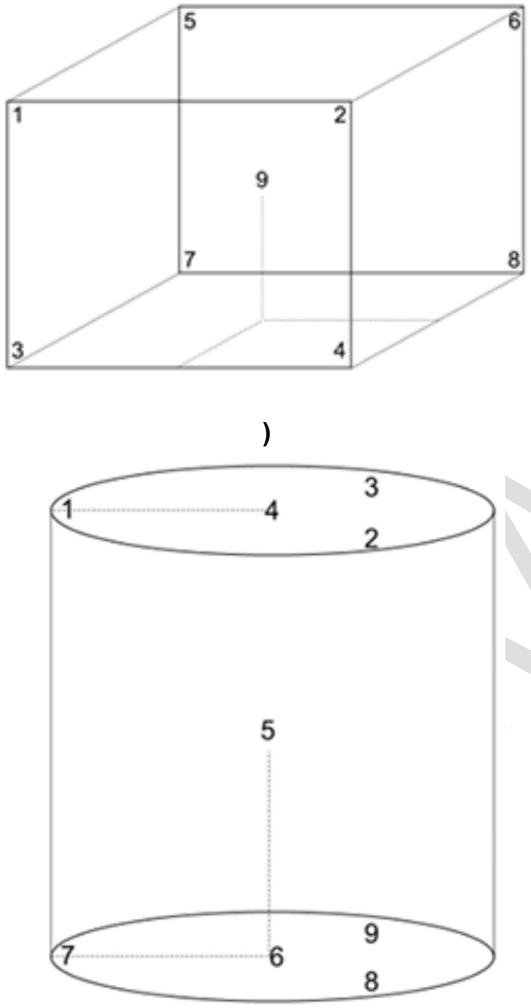

Figure 2 – Thermocouple Locations – Cylindrical Furnace (Working Zone)

6.2.7 Optical Pyrometer Method

6.2.7.1 Continuous lines that use utilizing induction heating shall be surveyed with optical pyrometers or other non-contact temperature measuring equipment positioned at various locations between or after the induction heating coils.

6.2.7.2 The location and number of pyrometers is dependent on the system design, the number of induction heating coils, and the dimensions of the product being processed. At a minimum of one pyrometer shall be positioned after each defined section controlled by a single power supply. The number of pyrometers, position and calibration shall be documented in a procedure. A survey and shall be done at a minimum annually.

6.2.7.3 The evaluation for this method shall be as follows:

a) Pyrometer calibration shall be performed either done by the pyrometer manufacturer or a third party lab certified to ISO 17025 using a blackbody furnace under highly controlled conditions

b) Use of a “master” pyrometer for comparison during production and validation

c) The evaluation of the temperature stability shall have product moving through the induction line for at least 30 minutes or 5 parts whichever comes first, while the temperature is recorded at a minimum every 5 seconds

d) For the purpose of the survey, the target temperature shall be defined for both austenitizing and tempering

e) The target temperature used for the survey can validate the austenitizing equipment for a range of +/- 150°F (+/- 66°C) for tempering equipment a range of +/- 200°F (+/- 93°C) from the defined target

f) From the survey readings, the target temperature shall be +/- 30°F (+/- 15°C) for austenitizing and +/- 20°F (+/- 10°C) for tempering. The survey readings may exclude temperatures that are irrelevant such as at product ends or transient irregularities.

g) If the temperature readings used for the survey are 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 requirements. This failure data shall be kept as a record, along with the actions taken to correct the reason for the failure.

6.2.8 Evaluation Records and Retention

The following records shall be maintained**;**

a) Evaluation report showing normal operating ranges of austenitizing and tempering continuous lines, and the actual temperatures being surveyed.

b) Initial surveys for new or major modification or major repair, such as:

1. Relocation of a continuous line/oven. The initial TUS may be waived if the continuous line/oven is designed to be portable—i.e., the continuous line has permanent wheels or other means of portability—but in some cases, a new periodic TUS can be necessary.
2. Increase in the maximum qualified operating temperature or decrease in the minimum qualified operating temperature.
3. Burner size, number, type, or location change.
4. Heating element number, type, or location change.
5. Changes to airflow pattern/velocity such as baffle positions, fan speed, fan quantity, etc.
6. Change of refractory thickness.
7. New refractory with different thermal properties.
8. Change of vacuum continuous line hot zone design or materials.
9. Change of control sensor (e.g., type, thickness of sensor assembly, gauge of the sensor elements, or hot junction construction).
10. Change of the control sensor location.
11. Change of combustion pressure settings from their original settings.

12. Change of continuous line operating atmosphere damper system settings from their original settings.
13. Control instrument or program change:
    i. Proportional versus high-low/off-on.
    ii. Change of the control instrument model or type.
    iii. PLC logic program change to the continuous line heat control scheme.
    iv. Adjustment of control instrument tuning constants, parameters, or rheostats.
14. Qualified work zone volume increase covering a volume not previously surveyed.
15. Qualified work zone location change covering a volume not previously surveyed.

c) For volumetric, probe and plane TUS methods, include work zone boundaries, the number and location of sensors, conveyance speed, recording frequency, process type (normalize, austenitize, temper, or stress relief), and instrument type used.

d) Throughput speed

For mechanical property method, include the annual mechanical property surveys, periodic analysis, control limits, testing method(s) used to perform the evaluation.

e) Pass/Fail criteria.

f) Relevant authority performing the survey.

6.3 System Accuracy Tests (SATs)

6.3.1 General

The SAT is performed to evaluate the accuracy of the continuous line controlling equipment as compared 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.

NOTE A method for evaluating the accuracy of process relevant equipment (sensors, measuring equipment and control devices, and other devices.)

6.3.2 Furnaces

The SATS shall also be performed on additional systems that qualify instrumentation as types A, B, C or D. SATS shall be performed using field test instruments, sensors, and extension wire that meet Table 7. SAT frequency is established in Table 7 after defining the Instrument types A, B, C, or D that are being employed in the process.

Added to Table 7 speed and time, pressure indicators (meet requirements from the manufacturer)

Table 7—Raw Material—Instrument Type and System Accuracy Tests (SAT) Interval

Temp. Uniformity	Instrument Type	Normal SAT Interval	Maximum Allowable SAT Interval	Max SAT Difference			Max Permitted Adjustment		
				°F	°C	% of Reading	°F	°C	% of Maximum Operating Temp.
±15 °F (±8 °C)	D	Monthly	Quarterly	±4	±2.2	0.4	±8	±5	0.38
	B or C	Quarterly	Semi-annually						
	A	Quarterly	Semi-annually						
±25 °F (±14 °C)	D	Monthly	Quarterly	±5	±2.8	0.5	±13	±7	0.38
	B or C	Quarterly	Semi-annually						
	A	Quarterly	Semi-annually						

7 Process Control

7.1 Instruments

7.1.1 Automatic controlling and recording instruments shall be used. Sensor shall monitor the continuous line working zone(s) and or qualified work zone and protected from continuous line atmosphere by means of suitable protective devices.

7.1.2 The heat treatment 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.

7.2 Heat Treatment Quench Requirements

7.2.1 General

The heat treatment 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 quench lance for tubular components.
c) Forced inside diameter pressure flow for tubular components.
d) Immersion bath type quench media
e) Waterfall type quench on the outside diameter.
f) Any combination of the above referenced processes.

7.2.2 Quench Facility Requirements

The quench of the heat treatment facility shall have the following requirements.

a) A documented procedure to control the quench process that shall include the following:
b) Transfer time is adequate to ensure that the material is able to meet the desired material properties.
c) Quench media and pressures shall be monitored and controlled to stay within the designed parameters to meet the desired material properties
d) Parts are adequately spaced to ensure they have received a proper quench
e) Concentration of synthetic quenchants shall be monitored

7.3 Movement of Product

A heat treat procedure shall be established and documented to control the movement of the product through the heat treat process to ensure that the material is heated sufficiently through the cross-section.

a) Identify the parameters that impact the movement of product
b) Equipment affecting product movement (i.e., motors, sensors, roll sets, cooling beds)
c) Verify and record the movement through the heat treat process during production

7.4 Furnace Atmosphere

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,
e) safety.

8 Heat Treatment Procedures

8.1 General

The heat treatment supplier shall maintain documented procedure(s) as described in this document.

8.2 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.

9 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/loading,

b) heating equipment/system,

c) quench systems (nozzles, agitation for bath type quenches, cooling towers),

d) temperature monitoring and controlling devices.

10 Manufacturing Process Specification(MPS)

10.1 General

The heat treatment supplier shall maintain a MPS(routing) to include, as a minimum, allowable levels for all continuous line heat treatment parameters including the process control variables listed in 10.2, 10.3, and 10.4. Heating, quench parameters, and inspection and test results shall be documented and maintained per Section 11.

10.2 Heat Treatment Parameters

The following are required 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,

b) heating zone temperatures,

c) quench pressure for dynamic spray quench processes,

d) agitation for bath type quenches,

e) throughput speed.

10.3 Quench Parameters

The following are quench parameters, as applicable.

a) quench media and type (water spray, water bath, polymer bath, oil bath),

b) quench media temperatures,

c) water spray uniformity and alignment, and

d) time immersed in quench bath media.

10.4 Test Requirements

The following are test and inspection requirements, 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

The following records shall be maintained.

a) Heat treatment process records, including quench pressure for dynamic type quench systems.

b) Heat treatment procedure.

c) Heat treatment procedure process qualification record (records of testing results)

d) Applicable heat treatment personnel qualification records.

e) Records required by this document.

f) All final inspection and test results required by the work order/specification.

11.4 Minimum Requirements for Heat Treatment Certificates

The following information shall be present on the heat treatment certificates, as applicable.

a) Name of heat treatment supplier.

b) Address of heat treatment supplier.

c) Date of certification.

d) Authorized signature and title of signatory.

e) Number of parts/components.

f) Part level serialization per heat treatment load, when required by product specification.

g) Heat treatment lot number, job number, or traveler number.

h) Material heat number/re-melt ingot number.

i) Material type, grade, or alloy designation.

j) Description of material being heat treated (dimension, shape, part number, serial number, if applicable.

k) Description of the process (austenitize, quench and temper, etc.).

l) Heat treatment temperatures if required.

m) Time at specified temperature, if required by the customer specification.

n) Quench media, if required.

o) Quench media temperature record, if required.

p) Furnace charts, if required.

q) Continuous line identification, if required.

r) Applicable heat treatment criteria/specification, if required.

12 Record Retention

Records required by this standard shall be maintained for a minimum of 10 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, or electronic identification and date;

b) 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 prepared for storage or transit in accordance with the documented procedure of the heat treatment supplier or the customer's purchasing document.

Bibliography

[1] SAE AMS2750, *Pyrometry*

[2] API RP 6HT, *Heat Treatment and Testing of Carbon, Micro-alloyed, and Low-alloy Steel, Wrought and Cast Components*

[3] ASTM A1100, *Standard Guide for Qualification and Control of Induction Heat Treating*