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1 Scope

- 1.1 This specification has been devised to clarify omissions and inconsistencies in various specifications concerning the establishment of furnace uniformity where omissions or ambiguities occur in the relevant specification. Where clear clarification from customer or end user already exists, the customer specification shall have precedence.

2 Reference Documents

- 2.1 ASTM A991
This specification defines practice for the conduct of uniformity surveys in a range of devices. Defines primary and secondary surveys and the requirements for carrying out uniformity surveys on loaded furnaces. It specifies that uniformity shall be considered as deviation from the set point but does not specify what that deviation should be – this is left to the customer or detailed product specification.
- 2.2 API 6A Appendix M
This is similar to ASTM A991, sets down the maximum volume that can be covered by 1 thermocouple (out of 9) and specifies the maximum deviation from furnace set point that is allowable. It does not specify whether the furnace should be loaded or unloaded.
- 2.3 ISO 10423:2009
This specification embodies API 6A 19th Edition (2004) and alone, contains requirements for the uniformity required within a furnace. As such it forms the basis for acceptance for NORSOK M650 and 3rd Party API, etc. certification

3 Applicable Processes for Calibration

- 3.1 Thermocouples (Inconel sheathed base metal) shall be manufactured in accordance with ASTM E608.
- 3.2 Calibration shall be traceable to national or international standards.
- 3.3 Calibration shall be within the temperature range to be surveyed and at intervals of not more than 100°C (200°F).
- 3.4 Temperature measuring devices shall be calibrated within the three months prior to use.
- 3.5 All shall be in accordance otherwise with ASTM A991 Section 5.2.

Note that Sulzer Pumps anticipate usage of this clarification document to be limited to batch type furnaces used within the range of 500°C (900°F) to 1200°C (2100°F).

4 Acceptance Standards

- 4.1 Sulzer Pumps considers the API 6A 19th Edition acceptance standards of uniformity to be appropriate for work carried out by thermal processing companies and hot-work process manufacturers to be appropriate to Sulzer requirements:
- 4.1.1 At Austenitising temperatures (>800°C / 1400°F) no survey thermocouple shall vary from the set point by more than ±14°C (±25°F).
- 4.1.2 At tempering temperatures (<800°C / 1400°F) no survey thermocouple shall vary from the set point by more than ±8°C (±15°F).
- 4.1.3 Maximum survey temperature shall be the maximum operating temperature of the furnace, but shall not be higher than 1100°C (2000°F) (per ASTM A991) unless specified in company SOP.
- 4.1.4 Surveys shall be carried out as a minimum at the minimum operating temperature of the furnace and 1100°C (2000°F) or the maximum operating temperature of the furnace, whichever is lower.
- 4.1.5 Intermediate temperatures that are significant to process may also be surveyed.

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5 Conduct of Survey

- 5.1 Primary and secondary surveys (as defined in ASTM A991 3.1.5 and 6) shall be conducted with full or typical operating load, but NOT empty.
- 5.2 A primary survey shall be conducted on commissioning of a new installation or after significant change to the furnace.
 - 5.2.1 Significant changes include (but is not limited to) change in fuel, burner configuration or type; furnace lining material or configuration; controller type or configuration; thermocouple location.
 - 5.2.2 General maintenance – patching of lining, replacement of burners or controllers with identical type, etc. shall not require repeat of the primary survey.
- 5.3 A secondary survey (which may be carried out at any single point temperature within the normal operating range of the furnace) shall be carried out within 12 months of the initial primary survey and within 12 months of each, subsequent secondary survey.
 - 5.3.1 A manufacturer may choose to conduct all surveys as primary surveys.
- 5.4 A furnace load as described above shall be compiled and recorded. Use of scrap material (risers, heads, feeders, etc.) is permitted.
- 5.5 Thermocouples shall be located at each corner of the load (constructed to embody the working zone of the furnace) with one thermocouple in the geometric centre (a minimum of 9 thermocouples) as per the diagrams in ISO 10423:2009 reproduced here.

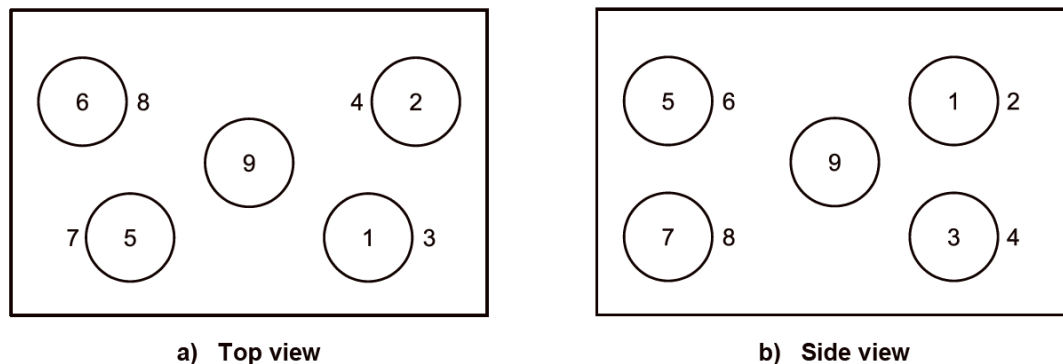


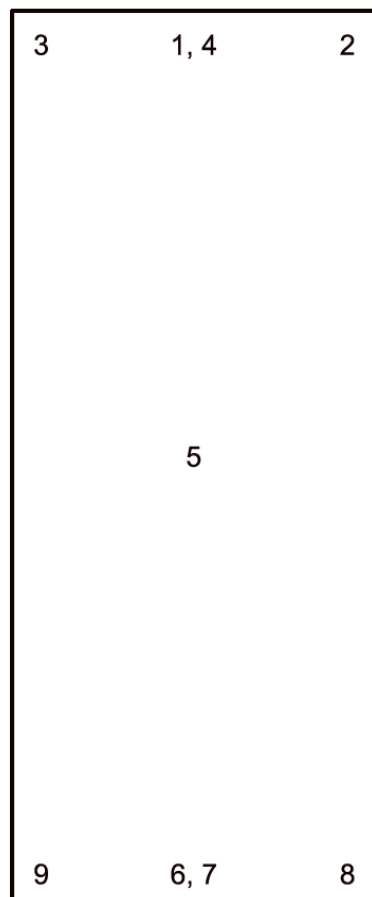
Figure M.1 — Thermocouple locations — Rectangular furnace (working zone)

- 5.6 To represent the conditions at the core of a component, each thermocouple may be mounted in a hole in a steel block, at least 100mm x 100mm x 200mm – the hole to be drilled to the centre of the block or tightly wired to the surface of the casting or forging
- 5.7 A digital logger with sufficient channels to record all survey thermocouples and the thermocouple output from the furnace controller (preferable) or a chart-recorder with sufficient channels and resolution to meet the requirement of the specification shall be used to record the calibration.
- 5.8 The load shall be cold enough to enable the positioning of the thermocouples and associated heat sinks in the furnace load.
- 5.9 The furnace temperature shall be monitored from the furnace controller.
 - 5.9.1 Commence recording data when the controller shows a temperature 100°C (200°F) below set point temperature.
 - 5.9.2 Record at least once every three minutes.

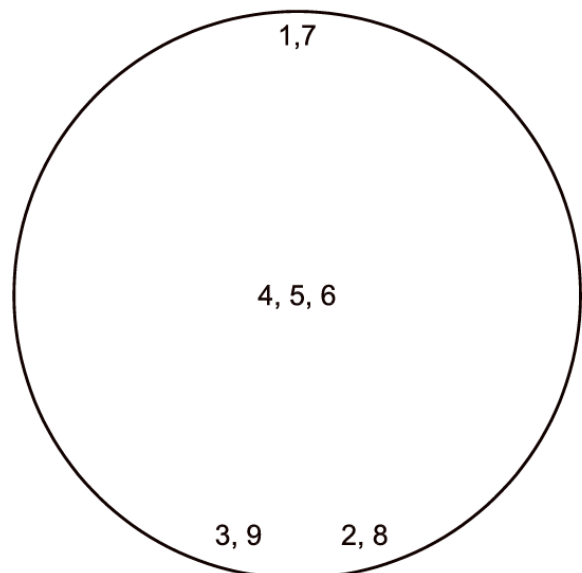
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- 5.9.3 Once set point temperature is reached, the temperature at all locations shall be recorded at 2 minute intervals, maximum, for at least 10 minutes, then readings shall be taken at 5 minute intervals, maximum for sufficient time (at least 30 minutes) to determine the recurrent temperature pattern of the working zone.
- 5.9.4 Before the set point is reached, none of the temperature readings shall exceed the set point by more than 14°C (25°F).
- 5.9.5 After the furnace set point is reached, none of the readings shall vary beyond the limits specified for the temperature set.
- 5.9.6 Repeat the process for intermediate set points and the maximum set point (maximum operating temperature or 1100°C / 2000°F)° as appropriate.



a) Side view



b) Top view

Figure M.2 — Thermocouple locations — Cylindrical furnace (working zone)

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6 Documentation of Survey Results

- 6.1 Organizations performing surveys in accordance with this test method shall keep pertinent documentation of the conditions and procedures used in the completion of the survey on file for a minimum of five years.
- 6.2 Pertinent documentation shall include, but not be limited to, the following:
 - 6.2.1 Specific identification of furnace surveyed,
 - 6.2.2 Date of the uniformity survey,
 - 6.2.3 Identification of the heat treat procedure,
 - 6.2.3.1 Set point temperatures,
 - 6.2.3.2 Type of atmosphere,
 - 6.2.4 Size and weight of steel product loaded in furnace at time of survey,
 - 6.2.5 Item identification numbers (lot, heat serial, etc.),
 - 6.2.6 Time and temperature data, including original temperature charts or original manually recorded data,
 - 6.2.7 Dimensions and location of the working zone(s),
 - 6.2.8 Number and location of the survey thermocouples,
 - 6.2.9 Largest observed temperature variation from the set points during the hold cycle,
 - 6.2.10 The time interval of the test, including the total elapsed time. Starting time and chart speed shall be marked on the original temperature charts,
 - 6.2.11 All pertinent equipment calibration information,
 - 6.2.12 Deviations from the test method including, but not limited to, thermocouple failure, malfunction, or disconnection.
 - 6.2.13 Name of personnel conducting the survey.
- 6.3 All data may be electronically recorded.

7 Interpretation of Results and Establishment of the Working Zone

- 7.1 The results of the primary survey describe the temperature uniformity of a furnace under a specific set of operating conditions. Results of the application of this test method shall be expressed as a variation from a temperature set point.
- 7.2 Establishment of the furnace working zone is made by comparing the temperature variation required by the product specification or agreed to by purchaser and supplier of heat treat services, with the variation from the temperature set point as determined by this uniformity survey.
- 7.3 The working zone may either be the entire heating volume, or it may only be some portion of the heating volume of the furnace. The working zone may be comprised of one or more heating zones in the furnace.

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