Daniel H. Herring | 630-834-3017 | heattreatdoctor@industrialheating.com

Temperature Uniformity Survey Tips

Part Two: Vacuum Furnaces

We have been discussing how to conduct temperature uniformity surveys (TUSs) and system accuracy tests (SATs) to comply with specifications such as AMS 2750D (Pyrometry), and we want to continue to expand that discussion. Let's learn more.

Tips for Conducting a Successful TUS and SAT – Vacuum Furnaces

Here is some advice gathered from years of doing surveys and from a number of industry experts on what you should watch out for when conducting temperature uniformity surveys in vacuum. Specifically:

1. The advertised "working zone" must be the same size as any racks or setup used (Fig. 1). In the field, it is not uncommon to find survey racks or thermocouples placed well within the actual working zone of the furnace. Nadcap auditors, for example, often measure the rack and compare it against the advertised working zone. If the advertised working zone is bigger than the rack, it will be a major noncompliance issue.
2. Make sure the thermocouples (used) are correct to the certification of calibration. Correction factors can be as much as 2.2°C (4°F) or 0.75% of the reading (whichever is greater), and if the wrong correction factors are used, the survey can be highly inaccurate.
3. Make sure the location of the sensors is correct to the record. If performing a TUS, be sure adjustments made to bring the working zone into a better uniformity and the sensor locations are correctly logged. It is not uncommon to find people adjusting locations incorrectly, making it worse and wasting time.
4. When crunching the numbers afterwards, make sure the approach to temperature is included in the "high" reading calculation for the test sensors *and* any other recording sensor(s). A sensor could overshoot a little, and if you do not analyze the approach and include it in the report, you are not certifying the furnace accurately.
5. Make sure the thermocouple (TC) wires are not bent sharply or stretched too tightly when routing them to their respective locations. The wires themselves go through phases of expansion and contraction. If too tight, they can become shorted during the process. A shorted reading will most certainly skew the results or cause a survey to be aborted.
6. Make sure to include the known deviation of the portable TUS recorder into the correction of the readings. An instrument may be off as much as 1°F or 0.1% of the reading (whichever is greater). This could add a deviation of 1.1°C (2°F) at 1095°C (2000°F). If not compensated for, this can seriously affect the results of the TUS, and it could be a major finding in a Nadcap audit.
7. Do not "step" the ramp for a TUS (to prevent overshoot). It is never a good idea to attempt this in production either. For example, do not ramp 16.5°C (30°F) a minute to 510°C (950°F), then 5.5°C (10°F) a minute into the 540°C (1000°F) setpoint of the TUS. It is imperative that production ramp rates are used for the TUS (Fig. 2). An auditor knows this can

Fig. 1. Single-chamber vacuum furnace temperature-survey rack in position *(Photograph courtesy of Solar Atmospheres Inc.)*

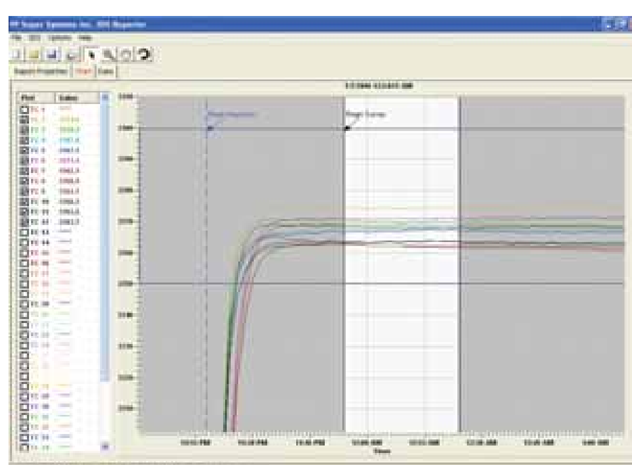

Fig. 2. Typical temperature uniformity survey chart *(Photograph courtesy of Super Systems Inc.)*

be a bad habit and will typically look for this. Again, this is a major finding should it be noted in a Nadcap audit.

8. Always measure the insertion of the controlling thermocouple before each survey. It must always be the same, which is critical to setpoint versus uniformity distribution. If a thermocouple is replaced and inserted to a different depth, the uniformity from setpoint may change.
9. Thermocouple wire feed-through assemblies and jack panels are an insidious source of EMF error. If using a thermocouple jack panel, make sure the panel is absolutely clean between the legs as even the slightest film could produce errors in the readings (Fig 3). Always keep dummy plugs in unused jack locations. The wires from the chamber feed-through to the back of the jack panel are also a potential source of error. Fiber insulation attracts and holds contamination and water vapor that can bridge the gap between the wires, causing a slight EMF error. It is important to keep in mind that even on the more forgiving type-K thermocouple, the difference between 300°C (572°F) and 301°C (574°F) is a mere 0.041 millivolts. It doesn't take much contamination to cause an error in the difference between the hot and cold junction of a thermoelectric circuit.
10. With a calibrated run-up box (thermocouple generator source), inject a signal into the jack panel to simulate a given temperature through every channel to ensure correct readings back to the official recording system. On vacuum systems, temperatures in the ranges of 93°C (200°F), 538°C (1000°F), 800°C (1475°F) and 1205°C (2200°F) are not uncommon input signals.
11. On average, TC jack-panel feed-through plates should be replaced every year as the female connecters become impregnated with process debris and hot-zone trace elements. Coupled with this, the springs become annealed causing loose connections and subsequent errs in the readings.

Fig. 3. Typical jack panel *(Photograph courtesy of Ipsen USA)*

12. Be absolutely certain that the instrument used to calibrate the portable TUS recorder meets the accuracy requirements of a "secondary standard," which is ±0.3°F or ±0.05%, whichever is greater. Many common field-test instruments do NOT meet this accuracy requirement. If you outsource the calibration, you should always have a current copy of the calibration from the field test instrument (used) and make sure it meets this requirement. In addition, the calibration should have been performed as the instrument is used. For example, if the field-test instrument is used as a thermocouple simulation source (sending the temperature signal to the device being calibrated), the appropriate thermocouple types should be checked while the instrument is in the *source mode*. Having a calibration certificate that shows how accurate an instrument is in read mode does not always qualify it in the source mode. Communicating these kinds of requirements to your supplier is very important to getting the service you require to pass your Nadcap audit without findings.
13. First, check the element resistance to ground. For example, one manufacturer's equipment is designed for 87-110 ohms prior to attempting a temperature survey. Do not attempt a survey if the resistance is bad on any particular zone. The readings should be fairly balanced prior to attempting a survey.

Fig. 4. TUS rack with metallic-sheathed thermocouples *(Photograph courtesy of Vac Aero International Inc.)*

14. Ensure load TCs are new and preferably (not required) from the same lot of source wire for ease of tracking deviation factors.
15. Make sure that your load TCs maintain correction factors that are less than the survey spread allowance. For example, surveying for a spread of ±5.5°C (10°F) and utilizing load TCs with correction factors of ±6°C (11°F) or higher is not desirable.
16. Extrapolating setpoint temperatures on load TCs in steps greater than 120°C (250°F) are not allowed. Load TCs for vacuum furnaces tested to AMS 2750D are supplied with certification sheets typically from 540°C (1000°F) up to 1205°C (2200°F) in 120°C (250°F) steps. Hence no extrapolation required.
17. Before starting a TUS survey, check that the furnace has recently passed its reference probe check.
18. Check all element connections to be sure that they are tight and show no signs of arcing.
19. Remove all lower-temperature materials and alloys from previously processed runs prior to conducting surveys. IH

For the remaining tips (20-33) and the conclusion of this column, please go to the online version on our website or at this direct link: www.industrialheating.com/htdr609