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Temperature Uniformity Survey Tips

Part One: Atmosphere Furnaces

Temperature uniformity surveys (TUS) are a key part of any good heat-treat operation. Specifications such as AMS 2750D (Pyrometry) have been referred to by some as the nemesis of many a good heat treater or quality engineer. However, if our goal is to ensure we are heat treating to the tightest practical tolerances, we must find ways to streamline the process for checking uniformity so that we will want to do it more often and with better accuracy. Let's learn more.

Up front, several important decisions need to be made: Will the surveys be conducted with or without atmosphere, and should they be done with or without a load? Due to safety concerns, most people agree that surveys in atmosphere furnaces should be run without an atmosphere present. The subject of using empty racks or workloads is more contentious. Some feel a survey using baskets or empty racks represents a worst-case scenario for uniformity. Others feel that an empty furnace does not mirror production conditions.

Commercial heat treaters often prefer using empty racks because they cannot predict what a typical load size or configuration will be. It is important to note that heating profiles should duplicate process parameters (i.e. do not slow down ramp to avoid overshoot with an empty furnace). Auditors will look for this type of detail. For captive shops (such as those running automotive components) that heat treat the same size and type loads every day, it may make more sense to run the survey with a load as it is more representative of production conditions. In addition, the heat-up data can be used to determine how long it takes a load to reach temperature so as to better predict soak times.

Fig. 1. Manual survey method for an integral-quench furnace (Courtesy of Super Systems, Inc.)

Conducting A Successful TUS and System Accuracy Test (SAT) in Atmosphere 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 a TUS in atmosphere furnaces. Although many of these comments apply to all types of furnaces, atmosphere styles are particularly challenging due to the amount of manual intervention needed to "feed" the thermocouple (T/C) wires through doors, etc. (Fig. 1). For this reason many companies offer devices that can be placed on a grid or in a basket and run through the furnace. Be aware that there are certain restrictions (e.g., time at temperature) that apply to these devices.

Survey Tips

1. Make sure the proper classification is given to each furnace. Keep in mind that one furnace can be classified and used in more than one way. You cannot use a furnace for a process for which it has not met temperature uniformity.
2. Take the proper number of measurements. Surveys require data points in two-minute intervals for each T/C, including clear evidence of ramp-up and clear evidence of soak (Fig. 2).
3. Be thorough. Make sure your records show all required details.
4. Make sure any resident SAT probes are not of the same T/C type as the control T/C. Also, the SAT thermocouple must be located within 3 inches of the control T/C to be valid. Have a calibration report for both the SAT probes and T/Cs. You now need to periodically perform SAT tests on freezers and quench oils (monthly is acceptable). Frequency of SAT depends on instrumentation type (as does TUS). You are now rewarded with longer times between surveys if you use load T/Cs.
5. Instrumentation calibration is mandatory. Make sure the company meets all calibration requirements for instrumentation. The certification must clearly state each is met, along with objective evidence. Each instrument parameter should be calibrated at least three points, and make sure the points calibrated cover the entire operating range.
6. T/C wire traceability is required. Calibration records are needed with clearly stated correction or error factors (these must be properly applied algebraically). Make sure any rolls of wire greater than 1,000 feet are calibrated at both the beginning and end of the purchased roll (use average between beginning and end in TUS), and make sure the beginning and end values do not differ by more than ±2°F (±1.1°C).

7. Use Type N for survey T/Cs. In many cases, they are now preferred over type K, from an initial cost and re-use basis.
8. Selection and placement of T/Cs is critical. Attention to every detail demanded by the specification is mandatory.
9. Be sure to maximize the contact between the T/Cs and the rack, test slug or part. If the integrity of the contact between these two surfaces is not maintained, you might be logging an extraneous temperature instead of process temperature.
10. Do not weld heat sinks to the survey frame since the contact area makes the heat sink larger than it should be. Heat sinks have been found to make the difference with respect to overshooting and also the degree of overshoot.
11. Understand the impact of the T/Cs' thermal mass. Every T/C has an effect on the temperature or heating characteristics of the product being measured. It's important to match the T/C to the job required.
12. Understand the compromise that must be made between T/C life and maneuverability. For example, while 1/8 inch (3.0 mm) diameter T/Cs are common, they are more rigid than say 1/16 inch (1.6 mm) diameter T/Cs.
13. Know and record the position of the control T/C in relationship to the survey T/Cs. Control T/Cs located too close to the walls or too far into the chamber can cause large temperature variations and different response times. After surveying, if the control T/C was replaced with a different type, different gauge-thickness wire, different protection tube or located in a different location, the survey must be redone.
14. Clearly define the work envelope. Workloads or parts that fall outside survey dimensions must be considered having been run in a nonconforming piece of equipment.
15. Have procedures for performing a TUS clearly documented. Make sure that during an audit, procedures for the TUS activity are readily available and that the in-house technicians who perform the surveys know the procedures and where to access them. If a third party performs the survey, make sure that the quality department reviews and signs off on the paperwork prior to filing it.
16. Make sure the equipment being used meets the specified accuracy and readability requirements. AMS 2750D, Table 3 defines a TUS device as a field test instrument. Calibration accuracy for the device is ±1°F (±0.6 °C) or ±0.1% reading in °F, whichever is greater.
17. Have documented procedures on how correction factors are used. Make this procedure as simple a possible, and provide examples so that pyrometry personnel and auditors can easily evaluate survey results and documentation on corrections used.
18. Make reporting easy. Since surveys take time to perform, make the reporting process simple, consistent and repeatable so that survey results can be documented and signed off, and technicians can focus on spending their time getting equipment ready for production.
19. Don't try to qualify a furnace for uniformity that is not required. If you are only running parts that require a class-5 furnace (AMS 2750D, ±25°F for example), don't try to achieve a uniformity that is tighter than that.
20. Design and fabricate a proper test rack. This is especially important when running a survey without a load. Be sure to place the T/Cs in the same location each time and run each TUS in as similar a fashion as possible.

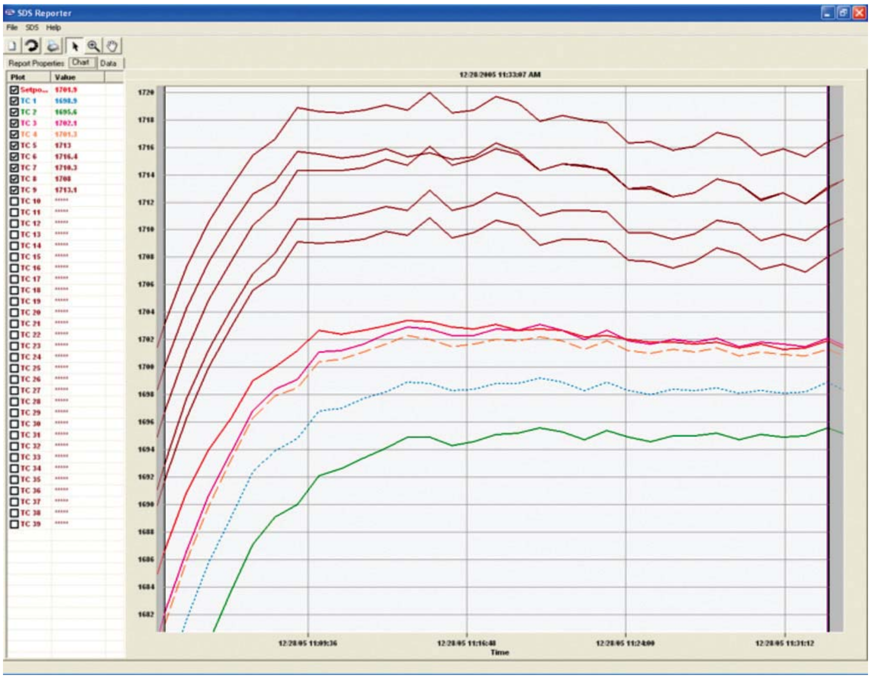

Fig. 2. Typical survey chart (Courtesy of Super Systems, Inc.)

Final Thoughts

Remember that each type of furnace is unique with different methods of construction, different heating/cooling capabilities and in a different state of repair. For this reason, we need standards that level the playing field. The intent of AMS 2750D and other specifications of this type is to ensure that one of the most common equipment variables, namely temperature, is taken into consideration in the overall quality scheme. Part Two will provide similar tips for vacuum furnaces while Part Three looks at ovens. **IH**

References (available online)